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Climate change and Food Security in Africa between perception and adaptation: an economic analysis

Ph. D. thesis by

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Summary

Chapter 1

Introduction

1.1. Background

Climate change is widely recognized as the most important global environmental problem whose scientific evidences are unequivocal. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen and the concentrations of greenhouse gases (GHGs) have increased significantly, driven by economic and population growth (IPCC, 2014). Continued high emissions of GHGs would determine an increase of severe, pervasive and irreversible impacts for many species and ecosystems and could amplify risks for natural and human systems (IPCC, 2014).

More than other major economic sectors, agriculture is particularly affected by weather alterations because it is climate – sensitive and highly dependent on natural equilibriums. Increases in temperatures, rainfall variations and growing frequency of extreme weather events are adding pressure to the global agricultural systems, which are already struggling to respond to increasing food demand due to global population expansion (FAO, 2015).

These risks are unevenly distributed and are usually greater for people living in developing countries because of their weak socio-economic condition, low capacity to react to environmental shocks and strong dependence on primary sector. Specifically, Sub-Saharan Africa is a region particularly vulnerable due to its exposure to global climatic drivers which, as a consequence of climate change, are likely to exacerbate the incidence and severity of extreme weather events (AMCEN, 2011; Collier et al., 2008) and increase damages on crop, livestock and fishery production (Campbell et al., 2016),

During the first decade of the century, sub-Saharan Africa made sound progress in its fight against hunger, with many regions witnessing an important decline in the prevalence and number of undernourished people (FAO, 2017). However, a reversal of this trend has occurred between 2015 and 2016. It has been attributed in many countries to adverse climatic conditions, often linked to the El Niño phenomenon and natural calamities such as drought or floods which resulted in poor harvests and losses of livestock (FAO, 2017). Recent estimates show that, in Sub-Saharan Africa the prevalence of undernourishment rose from 20.8 to 22.7 % between 2015 and 2016, and the number of people undernourished increased from 200 to 224 million (FAO, IFAD, UNICEF, WFP and WHO, 2017). At the same time, the proportion of population that has experienced severe food insecurity because of the existence of food access barriers has risen in the whole region (FAO, 2017). Low commodity prices and increasingly challenging on global economic conditions, coupled with the outbreak of conflicts, further exacerbated the food security and nutritional situation across the continent (FAO, 2017).

In this context, in order to enhance food production systems and improve resilience capabilities of rural people living in developing countries, it is crucial to understand what is the main link between food security and climate change. Once verified this connection, it is important to derive information about existing adaptation strategies aimed to minimize adverse climate change impacts on food production. Furthermore, a depth analysis of all factors influencing the adaptation propensity of rural communities is a fundamental prerequisite to define effective adaptation strategies and policies.

This thesis aims to develop each step of this analysis ‘process by using two empirical case studies in Sub-Saharan Africa. After an overview of climate change trends and impacts at global and regional scale, with a specific reference to agriculture, in the first part it was considered factors affecting households’ food and nutrition security under climatic change in developing countries. Indeed, among all possible elements characterizing vulnerable human systems (such as ecosystems and natural resources, agricultural sector, health, urbanization, social conflicts and migration) food and nutrition security represents the most urgent issue influenced by even more persistent climate stresses. A case study conducted in Uganda was utilized as empirical example on these factors. Uganda has been chosen because it represents the situation of many countries located in East-Africa, a sub-region characterized by the highest prevalence of undernourishment (FAO, 2017) and affected by climate-related phenomena (e.g. El – Niño) which exacerbate the already precarious food security conditions of poor rural communities.

The second part focuses on the adoption of adaptation strategies aimed at minimizing these adverse global warming effects, and analyses the role played by the perception of climate alterations in influencing farmers' behaviour, under the assumption that a proper understanding of weather modifications is a fundamental prerequisite to address farmers' decisions towards the adoption of effective adaptive actions (Maddison, 2007). A case study run in Guinea was used to empirically investigate the influence of climate change perception on the propensity of households to adapt. Guinea has been chosen because it well represents the condition of many countries located in West-Africa, a region where the majority of households are very poor, produce a quantity of food close to subsistence levels and face numerous constraints such as recurrent droughts, deforestation, soil acidity, nutrient depleted and degraded soils (Roudier, Sultan, Quirion, & Berg, 2011). In particular, in Guinea the impacts of climate change are mainly related to increased rainfall variability including more frequent events of short and intense rains and more frequent drought periods. Given that in Guinea the agricultural sector is mainly rainfed, a correct perception of these climate alterations is considered an essential prerequisite to design proper adaptation strategies able to preserve food production.

Main findings show that, among all possible factors influencing food security of people living in developing countries, climate changes have an important role. This make necessary to define proper adaptation strategies whose implementation is however influenced by the perception of these climate alterations and by specific socio-economic factors characterizing rural communities. Study's results confirm that effective policy actions aimed at improving food security and enhancing climate change resilience of smallholder farmers should be realized through a combination of innovative measures, stretching from school and other educational or training programs to climate change knowledge and information management, awareness, and climate-smart agriculture technology diffusion.

1.2. Research objectives and questions

With reference to a developing context, and using appropriate quantitative methods, the objectives of the thesis are the followings:

- Evaluate the links between food and nutrition security and climate change;
- Identify the strategic agriculture adaptation options implemented to cope with climate change-induced impacts in vulnerable areas;
- List the main drivers influencing the adoption of such adaptive actions and highlight the role played by climate change perception in farmers' decision making process.

To reach these objectives the following research questions are to be answered:

1. a) To what extent climate changes affect food security? b) What are the other socio-economic factors affecting household's food security? c) What policy measures could be put in place to improve food security under the on-going climate change?
2. a) Do households perceive properly the on-going climatic changes? b) How does this perception influence their adaptation behaviour? c) What are the other interacting factors that lead to the adoption of adaptation strategies?

The ultimate aim of the thesis is to provide information on the design of policies aimed at minimizing climate change impacts in terms of food and nutrition security and stimulate the adoption of proper and effective adaptation strategies to increase livelihood of poor rural population in developing countries.

1.3. Methodology and approach

The thesis investigates firstly the existence of a connection between climate change and food security. In particular, it analyses whether climate alterations have a significant and negative impact on food security. Thereafter, once identified some adaptation strategies aimed at minimizing such adverse climate change effects, it examines all possible drivers influencing the smallholder famer’s propensity to adapt. Two different case studies in Sub-Saharan countries such as Uganda and Guinea are used as empirical examples.

These countries are ideally suited for the two-step analysis presented in this thesis. They represent the situation of two opposite Sub-Saharan regions (Eastern and Western Africa) characterized by different natural resources endowments, different food security levels, different climate change conditions and then different challenges. In particular, while in Eastern Africa food insecurity represent the most urgent issue, in West Africa the understanding of and the adaptation to regional climate variability represents a fundamental prerequisite to preserve smallholder farmers’ livelihood.

Uganda was chosen as case study in the first part of the thesis (which is focused on the relationship existing between climate change and food security) because it well represents the precarious food security condition of some countries located in Eastern Africa. This Sub-Saharan region is the most affected by food insecurity[1], with one-third of the population estimated to be undernourished (FAO, IFAD, UNICEF, WFP and WHO, 2017). Such food emergency is further exacerbated by even more persistent climate variability resulting in increased frequency of extreme weather events such as drought, floods and landslides.

On the other hand, Guinea was selected as case study in the second part of the thesis (which is focused on the identification of drivers influencing the households’ propensity to adapt) because it represents some West African countries whose adaptation actions are fundamental to cope with the extreme climate variability characterizing this region. West Africa is peculiar in terms of climate change because it is characterized by important natural processes that drive the regional climate, including the movement of the Inter-Tropical Convergence Zone, the occurrence of the West African monsoon and El Niño-Southern Oscillation. These climate drivers have a significant effect on

[1] In Eastern Africa, about 33.9% of the population is estimated to be undernourished in 2016 while in the other Sub-Saharan regions the food security condition appears less urgent. Specifically, in Middle Africa, Western Africa and Southern Africa, the percentage of people undernourished is estimated equal to 25.8%, 11,5% and 8% respectively (FAO, IFAD, UNICEF, WFP and WHO 2017).

temperatures and precipitation patterns. In particular, persistent rain's irregularities affect seriously the livelihood of local population which are highly dependent on climate-sensitive economic activities such as rain-fed agriculture, livestock rearing, fisheries and forestry. To cope with these adverse impacts and reduce the vulnerability of rural communities, this Sub-Saharan region have identified a number of different actions such as (i) diversification and intensification of agricultural production; (ii) improvement of pest and disease forecasting and control; (iii) promotion of small-scale irrigation schemes; (iv) changes to the timing of cultivation in response to changing patterns of rainfall; and (v) improvements of food alert systems. However, the adoption of these practices is not enough widespread and a depth analysis on the smallholder's propensity to adapt is required.

Regarding the methodology adopted, in the Uganda case study, a time series analysis of rainfall and temperature data from Climate Change Knowledge Portal (CCKP) was performed to uncover underlying significant climatic trends occurring from 1965 to 2014. Socio-economic data collected by the Uganda National Panel Survey (UNPS) among 3,123 households and referred to the 2013/14 cropping season were utilized to estimate the prevalence of hunger in rural communities and identify with a regression model all possible drivers influencing the level of food security, with particular interest on the role played by climate change.

In the Guinea case study, an historical re-analysis of long-term series climatic data provided by the weather stations of Labè and Mamou and referred to the period 1981 – 2012 was conducted. Such information was coupled with socio-economic data collected through a questionnaire submitted to 296 households in 2012 and analysed in order to identify specific factors affecting the adoption of adaptation strategies and to provide information about the role played by climate change perception in household's decision making.

1.4. Outline of the thesis

The remainder of this thesis comprises six chapters. Chapters 2 to 4 defines the general context of the thesis. After presenting the most recent evidences regarding past, current and projected climate change at global and regional scale, Chapter 2 analyses all possible impacts of weather alterations in terms of agricultural productivity, with specific reference to agricultural sub-sector such as crop production, forestry, livestock and fisheries.

Chapter 3 presents specific climate change impacts in terms of global and regional food security. The concept of “food and nutrition security” and its multidimensional framework is presented. Current and projected food security status in Africa is examined. Possible climate change impacts on food security dimensions in such vulnerable context are discussed.

Chapter 4 provides an overview of diverse approaches characterizing adaptation strategies which could be put in place to cope with the adverse climate change impacts. Some agriculture adaptation strategies are discussed. Possible farmers' decision making determinants in the context of climate change adaptation are presented.

In Chapters 5 and 6 the two case studies are presented.

Chapter 5 addresses research questions 1a, 1b and 1c by exploring in depth the link between climate change and food security. It uses primary data collected over central, eastern, western and northern regions of Uganda, and proposes a methodology based on a three-step analysis. First, a rigorous analysis of climatic patterns was conducted with the aim to underlying significant climatic trends in the presence of random fluctuations. Second, a food security indicator was built in order to estimate the prevalence of food insecurity in rural communities. Population is clustered in three groups characterized by a specific food security level. An ordered regression model was performed with the aim to identify all factors affecting the level of food security and verify the importance of climate change among such factors.

Chapter 6 addresses questions 2a, 2b 2c by using primary data collected in the region of Fouta Djallon Highlands in Guinea. It is focused on the analysis of main factors affecting the adoption of adaptation strategies put in place to minimize adverse climate change effects and verify the role played by the perception of weather modifications at household level. It is based on a three-steps analysis. Firstly, an in-depth examination of climatic time series data aimed to verify the real magnitude of climate changes in the area was conducted. Information regarding the extent to which households living in the area actually perceived the recorded climatic modifications was derived. Secondly, a set of physical and socio-economic variables that could have an influence on farmers' decision to adapt have been selected. A logistic regression model aimed to identify the factors affecting households' adoption of adaptation strategies and to provide information about the role played by climate change perception in this process was run.

General conclusions are reported in Chapter 7 which summarizes main findings, discusses the implications for policy advice and reports some recommendations for further researches.

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Chapter 2

Climate change in Africa: trends, impacts and adaptation

2.1. Global climate change: past and future trends

Climate change, also called global warming, is one of the major challenges of our time and adds considerable stress to natural ecosystems and to human systems. Rising global temperatures has been accompanied by changes in weather and climate; rainfall patterns have been modified, oceans are becoming warmer and more acidic, ice caps are melting and sea level are rising. These modifications and relative consequences result global in scope and unprecedented in scale.

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decades since 1850, with an increase of the globally average combined land and ocean surface temperature of 0.85 °C over the period 1880 – 2012 (IPCC, 2013). The atmospheric and surface energy budget have a critical role in the hydrological cycle and also in the rate of change that occurs in the precipitation regimes. Increasing temperatures lead to greater evaporation and thus surface drying, thereby increasing intensity and duration of drought. However, the water holding capacity of air, which lead to increased quantity of water vapour in the atmosphere, determines an increase of moisture storms, thunderstorms, extra tropical rain or snow storms and tropical cyclones, with a consequent intensification of weather extreme events such as irregular rains and floods (Trenberth, 2011). As result, changes in many climate extremes have been observed since about 1950. In particular, while in some countries the intensity of extreme rainfall has increased, with consequent rise in rainfall – derived floods frequency (Ahern et al., 2005; Knapp et al., 2008; Hallegatte et al., 2013; Westra et al., 2014), in other regions extreme drought became more common (Famiglietti and Rodell, 2013). These events have determined negative and irreversible consequences on vulnerable ecosystems and have affected human systems directly dependent on them.

Considering changes in terms of cryosphere and sea level, while the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide and Artic sea ice have continued to decrease in extent, with a consequent global sea level rose of 0.19 m (IPCC, 2013).

This scenario is caused by a progressive increase in Greenhouse Gases (GHGs) concentrations in the atmosphere largely consequent to human activities. Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth and are now higher than ever. Indeed, this human evolution has determined a significant increase of atmospheric concentrations of carbon dioxide, methane and nitrous oxide that result unprecedented in at least the last 800.000 years (IPCC, 2014). Their effects, together with other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been dominant cause of the observed warming since the mid-20th century (IPCC, 2013).

At global level, continued emissions of GHGs will cause further warming and irreversible changes in all components of the climate, increasing the persistence of severe and pervasive impacts for human and natural systems.

In the Fifth Assessment Report of IPCC, the scientific community has defined a set of four new scenarios, named Representative Concentration Pathways (RCPs) which are identified by their approximate total radioactive forcing in year 2100 relative to 1750. These four RCPs include one mitigation scenario leading to a very low forcing level (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6.0) and one scenario with very high greenhouse gas emissions (RCP8.5) (IPCC, 2014).

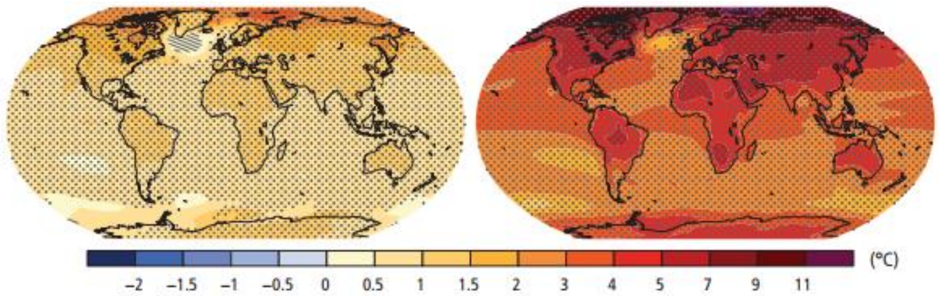
The increase of global mean surface temperature by the end of the 21st century is projected to be in the range 0.3°C – 1.7°C under RCP2.6, while it is likely to be 1.1°C – 2.6°C under RCP4.5, 1.4°C – 3.1°C under RCP6.0 and 2.6°C – 4.8°C under RCP8.5 (**Figure 2.1, a**).

In response to this surface warming, changes in water cycle will not be uniform. In particular, the contrast in quantity and intensity of precipitation between wet and dry regions and between wet and dry seasons will increase with some regional exceptions. Under the RCP8.5 scenario, the annual mean precipitation will likely to increase in the high latitudes and in the equatorial Pacific Ocean and decrease in many mid-latitude and sub-tropical dry regions (**Figure 2.1, b**) (IPCC, 2014).

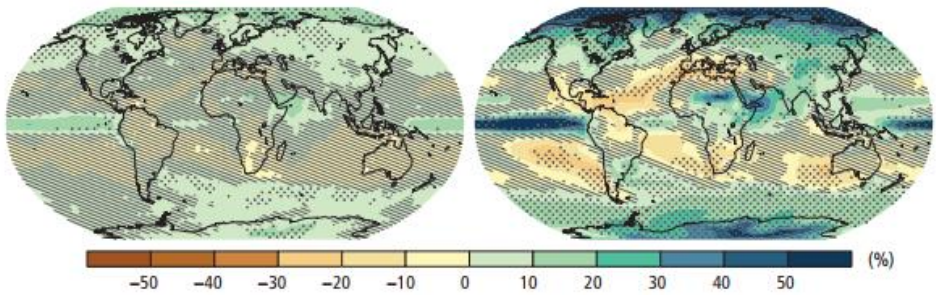
Figure 2.1 Projected changes in temperature and precipitation

a) Change in average surface temperature (1986-2005 to 2081-2100)

RCP2.6 **RCP8.5**



b) Changes in average precipitation (1986-2005 to 2081-2100)



Source: IPCC, 2014

Considering future changes in cryosphere, it is very likely that the Artic sea ice cover will continue to shrink and that Northern Hemisphere spring snow cover will decrease during the 21st century as global mean surface temperature rises. As result, glacier volume will further decrease (IPCC, 2013).

2.2. Climate change impacts on agricultural sector

Climate change has pervasive socio-economic consequences which result in changes on supply and demand for goods and services of all sectors of the economy.

However, more than any other major economic sectors, agriculture is highly dependent on local climatic conditions because of its reliance on climate-sensitive natural resources. This is the reason why it is expected to be highly affected by changes in climate that are projected for the coming decades.

All agricultural sub-sectors (crop production, forestry, livestock and fisheries) seem to be negatively influenced by climate change. Considering crop production, climate change can affect directly land productivity through yield losses and indirectly through losses and/or damages of important agricultural assets and infrastructures.

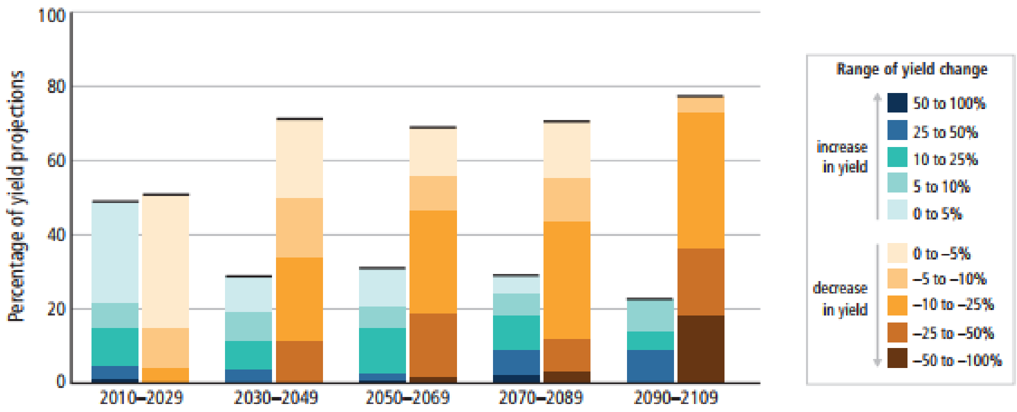
The observed effects of past climate trends on crop production are evident in several regions of the world. There is evidence that climate change has already negatively affected wheat and maize yields. In particular, some estimates show that, over the period 1980 – 2008, there was a 5.5 % drop in wheat yields and 3.8 % drop in maize yield globally (FAO, 2016). Furthermore, higher temperatures are associated with higher ozone concentrations which result particularly harmful to plants such as soybeans, wheat, oats, green beans, peppers and some types of cotton (Nelson et al., 2012). In this regard, recent studies have confirmed the damaging effects of elevated tropospheric ozone on yields, with estimates of losses for soybean, wheat and maize in 2000 ranging from 8.5 to 14 %, 3.9 to 15 % and 2.2 to 5.5 % respectively (FAO, 2016). At the same time, greater variations in precipitations imply an increase of short – run crop failure and long – run production decline.

Up to certain point, climate change may be beneficial for some crops in some places. In this regard, rising temperatures can lead to improved crop productivity in parts of tropical highland and high latitudes where cool temperatures are currently constraining crop growth. For instance, maize-based systems could benefit from warming at high elevation locations, as well as wheat and soybeans that can increase under high CO_2 concentrations and optimal temperatures (FAO, 2016). However, if temperatures exceed a crop’s optimal level, or if sufficient water and nutrients are not available, yields are likely to fall (FAO, 2016). Furthermore, extensive losses in agricultural productivity are also caused by an increased frequency of extremes events, especially floods and droughts.

In absence of actions aimed to moderate harms and exploit beneficial opportunities of climate change, agricultural sector is projected to decrease dramatically in terms of productivity.

Figure 2.2 illustrates summary projected changes in crop yields (mostly wheat, maize, rice and soy) due to climate change over the 21st century. Data for each timeframe indicates projections showing yield increase versus yield decreases for tropical and temperate regions and for adaptation and no-adaptation cases combined. Changes in crop yields are relative to the late 20th century level. Figure shows that the difference between projected yield increases and yield decreases tend to rise over time, with the percentage of yield decreases even more higher than the percentage of yield increases.

Figure 2.2 Summary projected changes in crop yields



Source: IPCC, 2014

Changes in temperatures and rainfall regime may also have considerable impacts on the ecosystem provisioning services provided by forests ad agroforestry systems on which many people depend (Nelson et al., 2012). Recent studies suggest that, in a wide range of forest systems, higher temperatures and changes in precipitation are increasing tree mortality through heat stress, drought stress and pest outbreaks (Allen et al., 2010; FAO, 2016). Many areas of boreal forests have experienced biomass productivity declines that have been attributed to warming-induced drought (FAO, 2016; Williams et al., 2013).

Considering the livestock activities, they appear vulnerable to climate change in a number of dimensions. Weather modifications can be expected to have several impacts on feed crops and grazing systems including (Hopkins and Del Prado, 2007; Thornton et al., 2009b): (a) changes in herbage growth brought about by changes in atmospheric CO_2 concentrations and temperatures; (b) changes in the composition of pastures, such as changes in the ratio of grasses of legumes; (c) changes in herbage quality, with changing concentrations of water-soluble carbohydrates and nitrogen at given dry matter yields; (d) greater incidence of drought, which may offset any dry matter yield increase; (e) greater intensity of rainfall, which may increase nitrogen leaching in certain systems. Furthermore, hot and humid conditions can cause heat stress in livestock, which will include metabolic changes, including reduced feed intake and thus a decline in productivity (Thornton et al., 2009b). In this regard, most livestock species with a comfort zone between 10 – 30°C, reduce their feed intake by 3 – 5 % per additional degree of temperature (Nelson et al., 2012). However, the vulnerability of livestock to heat stress varies according to species, genetic potential, life stage and nutritional status. In particular, increasing temperatures at higher latitudes are generally going to have greater impacts on livestock than lower ones, where local livestock breeds are often already quite well-adapted to heat stress and drought (Thornton et al., 2009b).

Finally, with regard to the fisheries sub-sector, models based on predicted changes in environmental conditions, habitat types and phytoplankton primary production predict a large-scale reduction of global marine fish catch potential, with an average increase ranging from 30 to 70 % in high-latitude regions and a drop of up to 40 % in the tropics (Cheug et al., 2010; FAO, 2016).

In this scenario, it is clear that global temperature increases, alterations in precipitation patterns and more frequent and intense climatic extreme events, combined with projections of decreases in global food supply and increasing global demand for food, would pose large risks to food security at global and regional scale.

2.3. Climate change dynamics in Africa

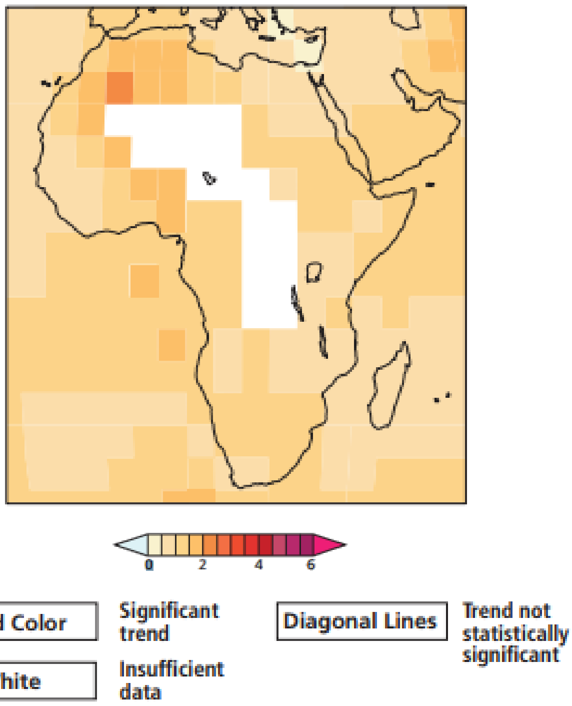
As illustrated in the previous paragraph, since agriculture is the most affected economic sector it is likely that populations highly depend on it could be the ones most adversely compromised. This is especially true in Africa where agriculture is frequently the largest contributor to the Gross Domestic Product (GDP) and is also the main source of rural employment. In this context, severe and prolonged droughts, flooding and losses of arable land due to the on-going climate change are reducing agricultural yields, are causing crop failure and losses of livestock and are worsening the precarious condition of local population which have limited resources to cope with adverse weather conditions or to recover from climate shocks.

Climate modifications and extreme weather events affecting African continent are not a recent phenomenon. Indeed, this part of the world has been dealing with the impacts of climate change since the 1970s. As shown in **Figure 2.3 a**, during the past century, near surface temperature has increased by about 0.5°C over most parts of Africa (except in the interior part of the continent where the data coverage has been determined to be insufficient to draw conclusions about temperature trends) (Niang et al., 2014).

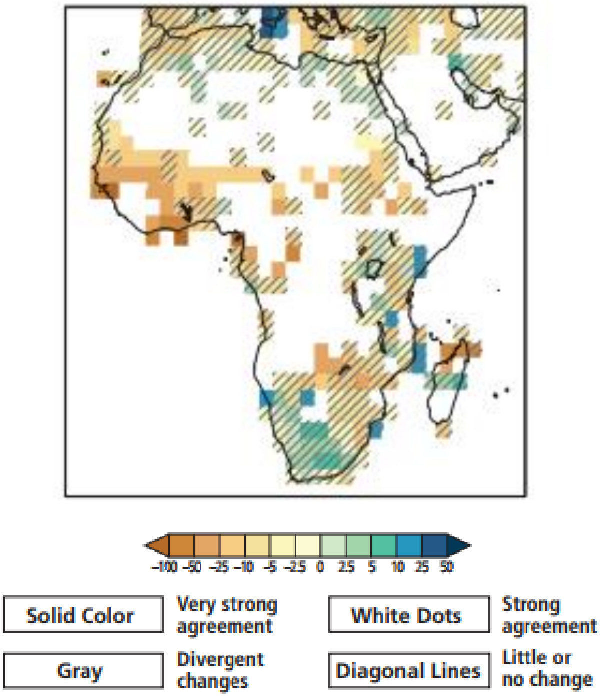
Annual trends of precipitations result less well identified due to lack observational data related to the past centuries. However, considering only the areas with sufficient availability of data, **Figure 2.3 b** shows that parts of the western and eastern Sahel region in northern Africa areas experienced decreases in annual precipitation while parts of eastern and southern Africa experienced annual increases of rainfall (Niang et al., 2014).

Figure 2.3 Annual temperature and precipitation changes

a) Trend in annual temperature over 1901-2012 (°C over period)



b) Trend in annual precipitation over 1951-2010 (mm/year per decade)



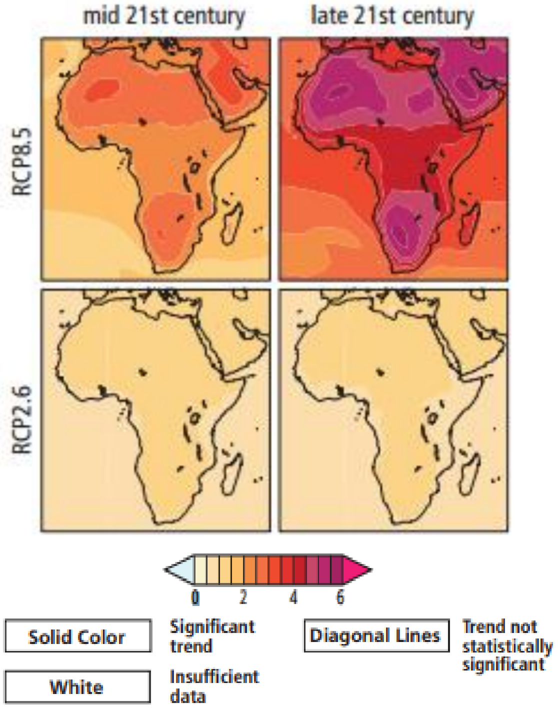
Source: Niang et al., 2014

Considering future climate changes, temperatures in Africa are projected to rise faster than global average increase during the 21st century (Christensen et al., 2007; Joshi et al., 2011; Niang et al., 2014; Sanderson et al., 2011; James and Washington, 2013). In particular, as shown in **Figure 2.4 a**, increases in mean annual temperature over most land areas of the continent are very likely in the mid and late 21st century periods for both RCP2.6 and RCP8.5 scenarios (Niang et al., 2014).

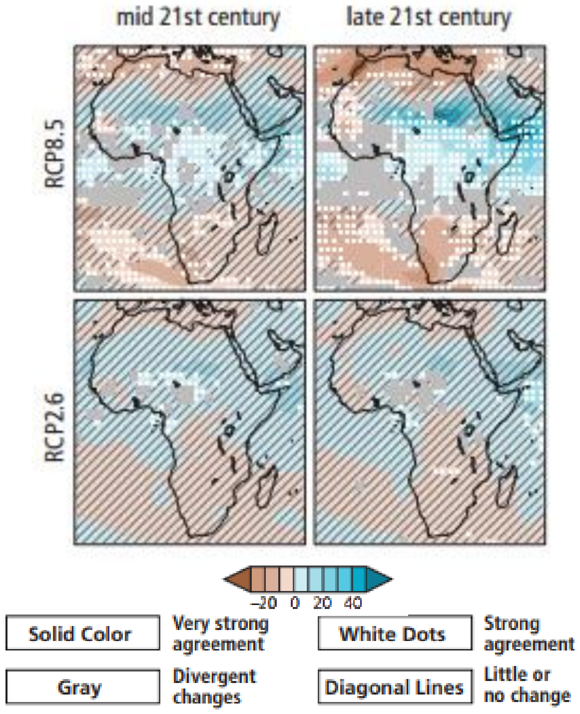
Precipitation projections are more uncertain than temperature projections. As illustrated in **Figure 2.4 b**, RCP8.5 projects decreases in mean annual precipitation over the Mediterranean region of the northern Africa and over areas of the south part of the continent in both mid and late 21st century periods, while they are projected to increase over areas of central and eastern Africa at the beginning of the mid-21st century. On the other hand, most regions of the African continent do not exhibit changes in mean annual precipitation in either the mid or late 21st century periods for RCP2.6 (Niang et al., 2014).

Figure 2.4 Annual precipitation change

a) Difference from 1986 – 2005 mean (°C)



b) Difference from 1986 – 2005 mean (%)



Source: Niang et al., 2014

2.4. African climate change between agricultural productivity, food security and adaptation

All projected climate changes occurring in Africa will have an unavoidable and direct impact on ecosystems and natural resources with consequences on agricultural productivity and then food security.

In Africa, all types of terrestrial ecosystems, including deserts, grasslands, savannah, woodlands and forests are changing with different dynamics. In this regard, the interaction between anthropogenic climate change, natural climate variability, livestock grazing and fuelwood harvesting have determined three specific trends. The first trend is connected with an overall expansion of desert and contraction of the total vegetated area, the second one consists in a large increase in the extent of human influence within green areas accompanied by a decrease in the extent of natural vegetation and the last trend appear as a complex set of shifts in the spatial distribution of the remaining natural vegetation types, with a net decrease in woody vegetation in western Africa and an increase of it in central, eastern and southern Africa.

Continuing changes in precipitation, temperature and carbon dioxide associated with climate changes are very likely to drive important future changes in the availability of natural resources (Niang et al., 2014). In this regard, impacts on water resources are difficult to determine given that the surface and groundwater hydrology are influenced by multiple and interacting drivers such as land use change, water withdrawals and natural climate variability. In Africa, the overall impact of global warming on groundwater resources is expected to be relatively small in comparison with impacts of other drivers such as population growth, urbanization, increased food demand and land use changes (Niang et al., 2014). However, broader-scale assumptions about drivers of future water shortages can mask significant sub-regional variability of climate impacts, particularly in water-stressed regions that are projected to become drier, such as in northern Africa and parts of southern Africa (Niang et al., 2014).

Agriculture, which provides a livelihood for about three-quarters of Africa's population, is considered particularly vulnerable because of extensive reliance on rainfed crop production. In this regard, high intra and inter seasonal climate variability, recurrent extreme weather events and losses of arable lands (due to desertification and soil erosion) are reducing agricultural yields, causing crop failure and determining losses of livestock, with negative impacts on rural and pastoralist populations (Beseda et al., 2009).

Climate change is very likely to have an overall negative effect on yields of major cereal crops across Africa, with strong regional variability in the degree of yield reduction (Liu et al., 2008; Lobell et al., 2008, 2011; Niang et al., 2014; Walker and Schulze, 2008; Thornton et al., 2009a; Roudier et al., 2011; Berg et al., 2013).

In this regard, simulations that combine all regions situated in Sub-Saharan Africa, suggest consistently negative effects of climate change on major cereal crops, ranging from 2 % for sorghum to 35 % for wheat by 2050 (Niang et al., 2014). The same negative impact characterizes the projected trend of the Northern Africa wheat production and maize-based systems of the Southern Africa (Niang et al., 2014).

However, in Western Africa temperature increases above 2°C are estimated to counteract positive effects on millet and sorghum yields due to increased precipitation, with positive effects stronger in the savannah than in the Sahel (IPCC, 2014).

Livestock systems in Africa face multiple stressors some of which could be exacerbated by climate change: (i) rangeland degradation, (ii) increased variability in access to water, (iii) fragmentation of grazing areas, (iv) sedentarization, (v) changes in land tenure from communal toward private ownership, (vi) in-migration of non-pastoralists into grazing areas, (vii) lack of opportunities to diversify livelihoods, (viii) conflict and political crisis, (ix) weak social safety nets and insecure access to land, markets and other resources (Niang et al., 2014; Solomon et al., 2007; Smucker and Wisner, 2008; Galvin, 2009; Thornton et al., 2009b; Dougill et al., 2010; Speranza et al., 2010).

Climate change is also contributing to oceanic acidification and increases in surface water temperature around the African continent, negatively affecting fish stocks and threating the livelihood of costal and small-scale fishing communities (Beseda et al., 2009).

All these climate change – induced impacts on food production determines unavoidable consequences in terms of African food security, which is currently affected by additional stressors such as poverty, environmental degradation, rapid urbanization and high population growth rates. In addition, increases in temperature, irregularities in precipitation and climate change – induced natural disasters are the major contributors to the spread of infectious and diseases e.g. diarrheal and malaria.

Climate change has also indirect effects on health through ecosystems degradation and unsafe water and poor sanitation which contribute to malnutrition, diarrheal diseases and other vector-borne diseases, with most impact on woman and children (Beseda et al., 2009). However, this high health vulnerability is also due to other drivers including lacking human and financial resources, inadequate public health care systems and poor governance (Niang et al., 2014).

All evidences of warming over the African continent, together with its possible impacts on ecosystems and natural systems, agricultural productivity, food security and human health, confirm the need of an immediate intervention to cope with climate change through effective adaptation strategies (IPCC, 2014). At the core of adaptation there is the capacity of a system to perceive clearly the on-going climate alterations. This awareness could be considered a prerequisite to cope with climate change and develop adaptation solutions whose configurations can improve the sustainability of a system.

In Africa, most national governments are initiating governance systems for adaptation. Disaster risk management, adjustments in technologies and infrastructure, ecosystem-based approaches, basic public health measures and livelihood diversification are reducing vulnerability, although these efforts tend to be isolated and not sufficient to address long-term impacts of climate change (IPCC, 2014).

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Chapter 3

Impacts of climate change in Africa: the food security implications

3.1. Food security: a multidimensional framework

Climate change has severe and pervasive impacts on natural systems and affects many aspects of human life. Among them emerge possible implications that this phenomenon has in terms of global and regional food security. In particular, increasing temperatures and alterations in the regimes of precipitation are adding pressure to the global agricultural systems, which are already struggling to respond to expanding global demand for food. This directly translates into additional risks for food and nutrition security of poor people living in developing countries.

In order to realize a composite analysis of the overall impact of climate change on food security, it is necessary to investigate in depth the meaning of terms like "food security", "food security and nutrition", and "food and nutrition security" that have evolved over several decades, based on different perspectives by leading professional communities of practice, especially nutrition and public health experts and professional groups working in the socio-economic, food and agriculture domains. At the same time, it is essential to examine carefully all food security dimensions – availability, access, utilization and stability – to well understand the underlying characteristics that can differ across regions and over time and that are differently influenced by climate change effects.

3.1.1. Evolution of underlying concepts and definitions of Food security

The basic concepts underlying the terms "food security" and "nutrition security" were articulated in the early 1940s during World War II. In 1943, forty-four forward-looking governments met in Hot Spring (Virginia, USA) to consider goal of freedom from want in relation to food and agriculture (CFS, 2012). They concluded that "freedom from want" meant a secure, adequate and suitable supply of food for every man, woman and child where “secure” referred to the accessibility of food, “adequate” referred to the quantitative sufficiency of the food supply and “suitable” referred to nutrient content of the food supply (Willaarts et al., 2014). However, this first definition changed during the following decades.

A food supply-based definition of food security was developed in 1974, when a World Food Conference, after a succession of poor harvests worldwide, defined food security as “the availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and offset fluctuations in production and prices” (CFS, 2012).

Emphasis on consumption is closely identified with the seminal study of Amartya Sen (1981) who expanded the concept of food security with a focus on the entitlements of individual and households. In particular, he revealed that food supply was not sufficient to guarantee food security. Indeed, in many cases of famine, food supplies were not significantly reduced, while a number of social and economic factors, such as declining wages, unemployment, rising food prices and poor food-distribution systems, led to starving among certain groups in society. In this renowned work Sen highlight that food related problems are influenced not only by the food production and agricultural activities, but also by the structure and processes governing entire economies and societies) which have to guarantee physical and economic access to the food (Pangaribowo et al., 2013).

The current terminology in use, as adopted from the1996 World Food Summit, emphasizes the multidimensionality of food security: “food security exists when all people at all-time have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO, 2000).

As the term “food security” evolved, the term “nutrition security” emerged in 1990s with the aim to include nutritional aspects into food security. Unlike food, that is mostly defined as any substance that people eat and drink to maintain life and growth, nutrition adds the aspects of health services, healthy environment and caring practices (Pangaribowo et al. 2013). The evolution of the “nutrition security” concept lead to the recent definition of FAO, which has developed the following draft formulation: “Nutrition security exists when all people at all times consume food of sufficient quantity and quality in terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education and care” (CFS, 2012). With the aim to combine the two concept above, the terms of “food security and nutrition” and “Food and nutrition security” emerged. While in the first term, the food security element is considered a prerequisite of an adequate nutrition status, the second-one highlights the integral linkage between food security and nutrition, which are considered parts of a unitary element. UNICEF and FAO have developed formulations for both terms and define “Food and nutrition security as a state achieved when adequate food (quantity, quality, safety, socio-cultural acceptability) is available and accessible for and satisfactorily used and utilized by all individuals at all-times to live a healthy and active life” (CFS, 2012; UNICEF, 2008) while “Food and nutrition security is considered achieved when all people at all times have physical , social and economic access to food of sufficient quantity and quality in terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education and care”(CFS, 2012).

The terms “Food security”, “Food security and nutrition” and “Food nutrition” are commonly considered interchangeable but they are sometimes used in ways specifically intended to make a distinction between food security and nutrition or with the aim to highlight the relationship between food and nutrition (CFS, 2012).

On the other hand, concepts such as food insecurity, hunger and undernutrition are linked but not synonymous (Ghattas, 2014).

A situation of “food insecurity” exist when people do not have adequate physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (CFS, 2012). It may be caused by the unavailability of food, insufficient purchasing power, inappropriate distribution or inadequate use of food at household level, poor conditions of health and sanitation and inappropriate care and feeding practices. This precarious condition could be chronic, seasonal or transitory. In particular, people face "chronic" food insecurity when they are already poor and lack the resources to meet their basic needs on a daily basis. At the same time, people face "transitory" food insecurity when they are initially not poor but face the risks for which they are inadequately protected (Nelson et al., 2012).

On the other hand, the term hunger, which has often been used interchangeably with food insecurity to garner action to combat it (Mason et al., 2001), is used to identify "an uncomfortable or painful sensation caused by insufficient food energy consumption" and could refer to short-term physical discomfort or to severe life-threating lack of food (Ghattas, 2014). Hunger is not synonymous with malnutrition or undernutrition. In particular, huger occur when people do not have access to the amount of dietary energy needed for their normal level of activity. If the situation persists over long time, it leads to undernutrition (CFS, 2012)

Finally, undernutrition is considered an outcome of the undernourishment state and/or poor biological use of nutrients consumed as result of repeated infectious disease. It includes being underweight for one's age, too short for one's age (stunted), dangerously thin for one's height (wasted) and deficient in vitamins and minerals (micronutrient malnutrition) (FAO, IFAD and WFP, 2015).

The world continues to face challenges to achieving food security because of recent global dynamics (Ghattas, 2014): (a) the role of food insecurity in times of political instability was evidenced by the riots that followed rising food prices in 2007 – 2008; (b) the multiple consequences of economic shocks and resulting food insecurity not only included reductions in food consumption and dietary energy intake, but also compromised diet quality and diversity; (c) largely stemming from poverty and inequalities, food insecurity breaches the basic human right to freedom from hunger and to enough nutritious and safe food.

3.1.2. Food security dimensions

The four pillars of food security implicitly identified in the previously definitions are: availability, access, utilization and stability. The nutritional dimension is integral to the concept of food security (Nelson et al., 2012).

While the first three dimensions comprises a physical determinant, the last one represent a temporal determinant.

Food availability refers to the amount of food that is available in a population during a certain period of time (Pangaribowo et al. 2013). It is related to the supply of food through production, distribution and exchange (Gregory et al. 2005). At national level, this food dimension results a combination of domestic food production, food imports and exports, food aids and domestic food shocks, while at household level it is linked with own food production and food exchange in local markets. According to Sen’s core thesis, which consider this dimension not sufficient to guarantee that everyone is free from hunger (Sen, 1981), food availability is considered an insufficient predictor for food and nutrition security (Pangaribowo et al. 2013). In this regard, although in most countries and regions, high food availability is associated with relatively low presence of undernourishment, outcome indicators show that high food availability does not always guarantee high food security (FAO, 2015).

Food access refers to the affordability and allocation of food and it is ensured when all household have enough physical and economic resources to obtain food in sufficient quantity and quality. Economic access is determined by disposable income, food prices and access to social support (FAO, IFAD and WFP, 2013). Physical access is determined by the availability and quality of infrastructures, including ports, roads, railways, communication and food storage facilities and other installations that facilitate the function of markets (FAO, IFAD and WFP, 2013). At individual level, the accessibility of food is heavily influenced by social variables, including gender positioning and power hierarchies within households (FAO, 2015). As food availability, also the access dimension does not in itself guarantee good predictors of food security level.

Utilization emphasizes the nutritional aspects of food security. It is considered a measure of a population's ability to obtain sufficient nutritional intake and nutrition absorption during a given period (Pangaribowo et al. 2013). Sufficient energy and nutrient intake includes nutritious and safe diets, a clean environment, access to health care, diversity of diet and intra-household distribution of food (FAO, 2015). Food utilization includes two distinct sub-dimensions. The first is captured by anthropometric indicators affected by undernutrition that are widely available for children under five years of age (which are considered an effective approximation of the nutritional status of the entire population), and includes wasting (being too thin for one's height), stunting (being too short for one's age) and underweight (being too thin for one's age). The second dimension is captured by a number of determinants or input indicators that reflect food quality and preparations together with health and hygiene conditions, determining how effectively available food can be utilized (FAO, IFAD and WFP, 2013).

Food stability refers to the stability of the three dimensions above: availability, access and utilization. This temporal determinant of food security is linked with exposure to short-term risks which can endanger long-term progress. Two types of indicator have been identified to measure the extent and exposure to risks. The first group of indicators include the area equipped for irrigation, which provides a measure of the extent of exposure to climatic shocks, and the share of food imports in total merchandise exports, which captures the adequacy of foreign exchange reserves to pay for food imports. A second group of indicators captures risks or shocks that directly affect food security, such as swings in food and input prices, production and supply (FAO, IFAD and WFP, 2013).

3.2. Climate change impacts on food security in the African context

3.2.1. Current food insecurity in Africa

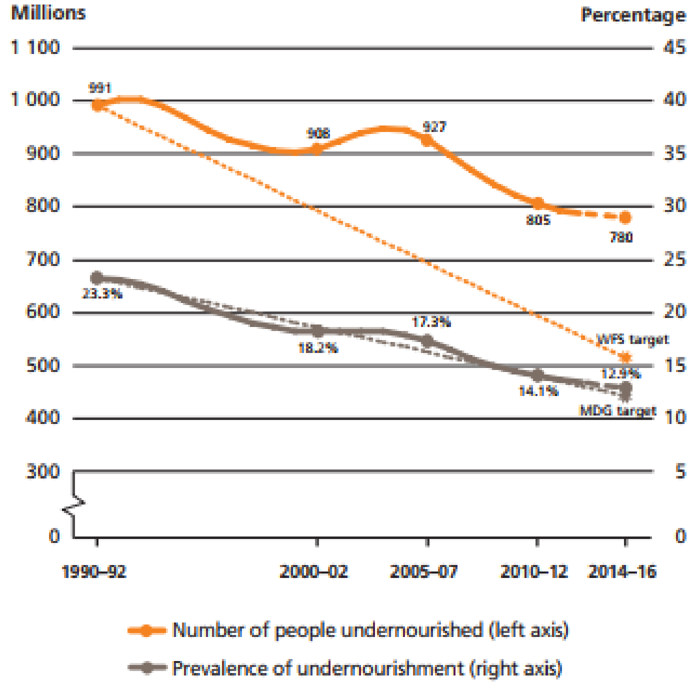
Although several progresses have made to reduce hunger at global level, food security instability continues to represent a serious threat at global level, given that a large number of people still lack the food they need for an active and healthy life (FAO, IFAD and WFP, 2015). Food insecurity, poor conditions of health and sanitation and inappropriate care and feeding practices are still the major causes of poor nutritional status of many people around the world and particularly in developing countries.

Today, about 765 million people are undernourished globally (FAO, IFAD and WFP, 2015). The share of undernourished people in the population, or the prevalence of undernourishment has decreased from 18.6 % in 1990 – 92 to 10.9% in 2014 – 16 while, during the same period, the number of undernourished people has declined by 21.4 % globally (FAO, IFAD and WFP, 2015). In developing countries, where an estimated population of 780 million people were undernourished in 2014 – 16 (FAO, IFAD and WFP, 2015), the decline of both number and prevalence of undernourished people is more pronounced than in other part of the world, with wide regional differences. In this regard, while some regions have made remarkably rapid progresses in reducing hunger, high level of food insecurity persist in a large number of countries among them emerges Sub – Saharan Africa which has the largest share of undernourishment.

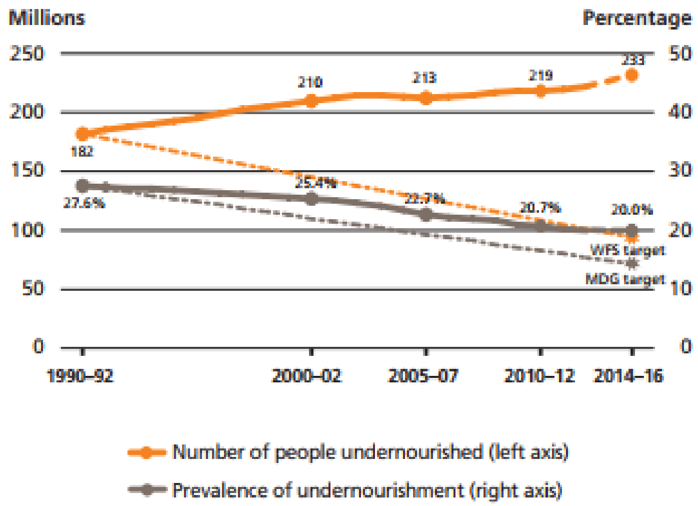
With reference to the period 1990-2015, **Figure 3.1** shows progresses in the prevalence of undernourishment respect to World Food Summit (WFS) goals and MDG achieved by developing countries in general and Sub – Saharan countries in particular. The estimates related to the prevalence of undernourishment suggest that the developing regions have almost reached the MDG hunger target, while they have missed the WFS target. In contrast, Africa as a whole (and Sub – Saharan Africa in particular), result far from both these two targets.

Figure 3.1 The trajectory of undernourishment in developing regions and in Sub-Saharan Africa

a) Developing regions progress achieving the MDG and WFS targets



b) Sub-Saharan Africa progress towards achieving the MDG and WFS targets

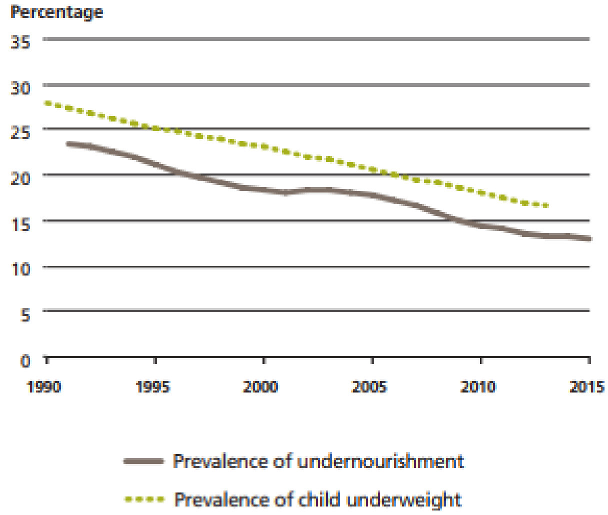


Source: FAO, IFAD and WFP, 2015

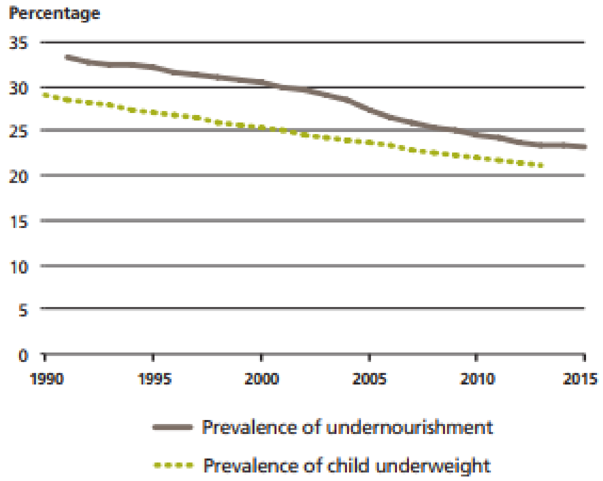
Proportion of people who suffer from hunger could be also analysed comparing trends in undernourishment and underweight. While the first indicator represents a state of inability to acquire enough food, defined as a level of food intake insufficient to meet dietary energy requirement, the underweight status is influenced by different factors (calorie or protein deficiency, poor hygiene, disease and limited access to clean water) which could impede the body's ability to absorb nutrients from food and eventually result in manifestations of nutrient deficits such as stunting, wasting and underweight (Ghattas, 2014). The food security dynamics represented by these two indicators are illustrated in **Figure 3.2**. It shows that, from 1990 to 2015, in developing regions the prevalence of child underweight moved from 27.4 % to 16.6 %, while the prevalence of undernourishment declined from 23.3 % to 12.9 % (**Figure 3.2 a**). The same trends characterized Sub-Saharan countries, where undernourishment and child underweight were looming large at the beginning of the 1990s, with both indicators exceeding 25 % (**Figure 3.2 b**).

Figure 3.2 Prevalence of undernourishment and underweight of children under five years in developing regions and in Sub-Saharan Africa

a) Developing countries



b) Sub-Saharan Africa



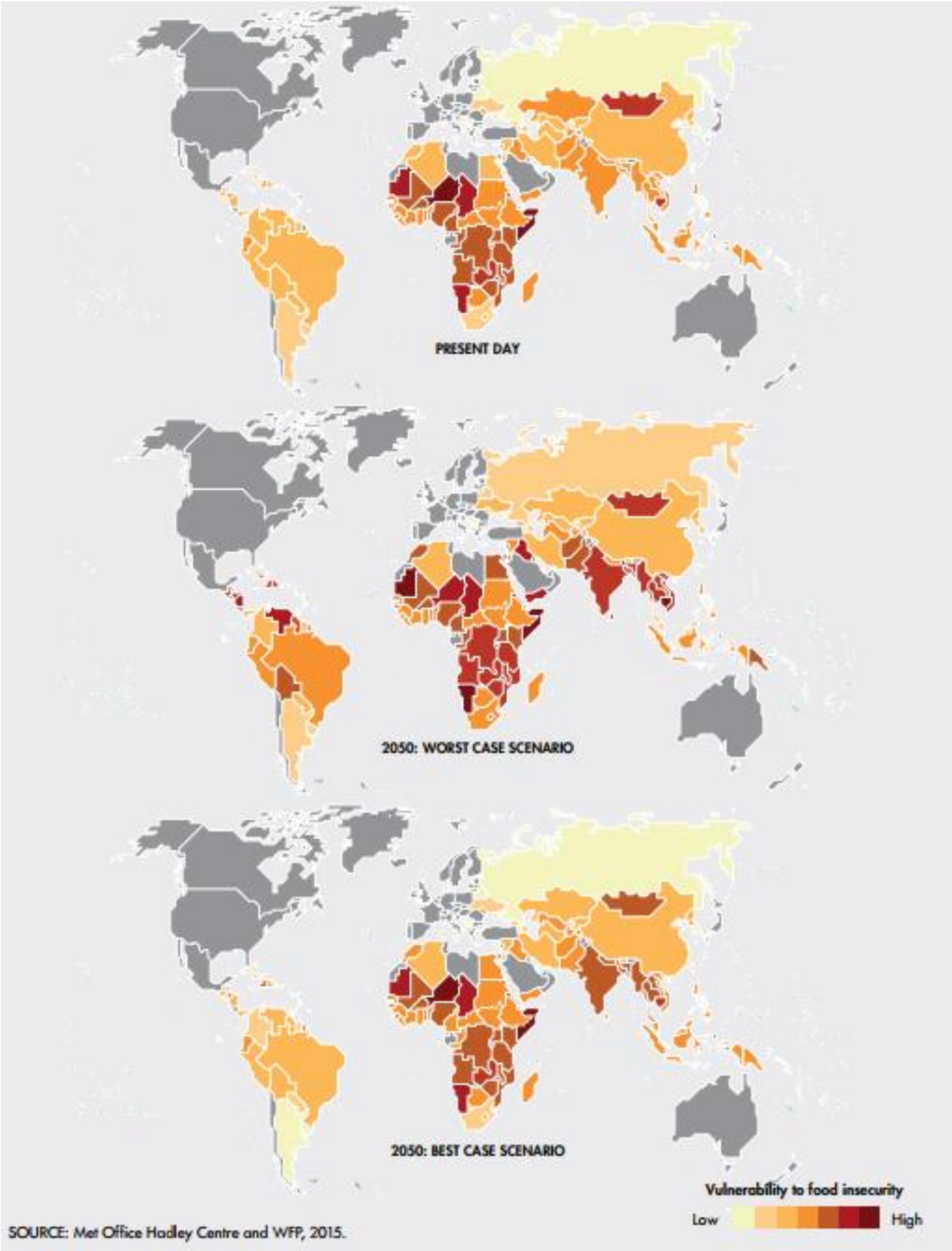
Source: FAO, IFAD and WFP, 2015

Although climate change poses concrete threats to future global food security, the likely impacts will differ by region, country and location and will affect different population groups according to their vulnerability (FAO, 2016).

Figure 3.3 shows the vulnerability occurring today and projected for 2050 under different scenarios: a worst case scenario, with high emissions (RCP 8.5) and no adaptation and a best case scenario with low emissions (RCP 2.6) and high level of adaptation.

In all these scenarios, the greatest food security vulnerabilities are seen in Sub-Saharan Africa where millions of people are likely to face significant risks of climate change by 2050s. This territory is followed by South Asia, South-East Asia and Latin America, where the prevalence of food vulnerability is less persistent. Furthermore, while under the best scenario some countries experiment a little decrease of vulnerability from present day level, under the worst scenario, the increase in vulnerability appear dramatic all over developing world (FAO, 2016).

Figure 3.3 Vulnerability to food insecurity in the world



3.1.3. Impacts of climate change on food security dimensions

Climate change and weather variability affect all dimensions of food security in different ways. The major expected climate change impact on food security is through food availability due to changes in agricultural productivity. In particular, climate change affects food availability through its increasingly adverse impacts on crop yields, fish stocks and animal health and productivity, especially in Sub-Saharan Africa and South Asia, where most of today's food insecure live (FAO, 2016). Food availability in Sub-Saharan Africa is directly affected by many aspects of climate change like temperature increase, change in rainfall amount and patterns, raising atmospheric concentrations of CO_2, change in climatic variability and extreme events and sea water rise (Chijioke et al., 2011; Zewdie, 2014).

While the link between climate change and food security has been mostly explored in relation to impacts on crop production or food availability, poor evidences exist with reference to other key dimensions namely food access, food utilization and also food stability (Esham et al., 2017)

The relationship between climate change and food access is complex. Empirical evidences showed a strong correlation between economic growth and rainfall variability. In particular, while wetter periods are associated with higher GDP growth, dryer years are linked with lower or even negative growth (Conway and Schipper, 2011, WFP, 2012). This means that climate variability can affect food access indirectly with modification of household economic conditions. Furthermore, some other studies have quantified the potential impact of rising temperatures in terms of increase in food prices (Fisher et al. 2002, Nelson et al 2009). In particular, in Sub – Saharan African countries lower yields caused by weather modifications and climate hazards, could result in higher food prices, together with losses of income due to potential increases in damage to agricultural production. Due to this high food price, households may be forced to reduce both quality and/or quantity of food, consume less preferred food and allocate food only to certain household members (Chijioke et al., 2011; Zewdie, 2014). In addition, an increase in the frequency of extreme events impairs food transport and other system infrastructures which are essential to transfer food products from the producers to consumers.

The most significant component of food security in a changing climate, but least studied, is food utilization. Climate change determines negative implications in terms of food utilization through reduced calories intake due to insufficient availability of food, reduced dietary diversity and its nutritional value due to increases of food prices, and reduced ability of human body to absorb essential nutrients from food due to increased disease burden. Climate change can also exacerbate incidence of infection diseases (such as diarrhoea or malaria) thereby increasing the caloric requirements of affected populations, reducing the body’s absorption and utilization of essential nutrients, and then increasing the overall nutrition needs (WFP, 2012).

Finally, the stability of all these food security dimensions is affected by increasing frequency and intensity of weather extreme events, consequent yield losses and instability of agricultural income.

In face of this context, it is important to consider that climate change cannot be seen as a “stand alone risk factor” but rather as an amplifier of existing food security risks and an additional strain on institutional infrastructures (Huynen et al., 2013). As result, climate change impacts on food security should be analysed in depth taking into account the influence of other environmental, socio-economic and institutional elements characterizing local communities.

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Chapter 4

Adaptation challenges in Africa: the role of the perception

In face on climate change, whose impacts influence many aspects of human life, there is the need of effective adaptation strategies able to anticipate adverse effects of climate alterations by taking appropriate actions to prevent or minimize damages they cause and taking advantage from opportunities they generate. Before analysing all possible drivers influencing the adoption of adaptation strategies, it is necessary examine the meaning of terms such as "vulnerability", "uncertainty" and "adaptive capacity", which represent core elements of the adaptation notion.

4.1. Vulnerability, uncertainty and adaptive capacity

Human society has a long history of coping with weather-related hazards such as temperature and precipitation extremes. However, recent anthropogenic emissions of Greenhouse gases (GHGs), driven by largely economic and population growth, have determined an increase in the intensity and frequency of these climate alterations. Such adverse impacts of human-induced climate changes could be significantly reduced through adaptation, which is defined as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2014). The adoption of adaptation strategies can contribute to the well-being of populations, the security of assets and the maintenance of ecosystems, goods, functions and services (IPCC, 2014).

Different adaptation options exist in all sectors and regions, with diverse approaches depending on their context in vulnerability, uncertainty and adaptive capacity.

Vulnerability is considered the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt to climate change (IPCC, 2014). The vulnerability is determined not only by the likely responses of the resources, but also by the availability of them and, crucially, by the entitlement of individuals and groups to call on these resources. In synthesis, the vulnerability of a system to climate change is determined by its exposure, by its physical setting and sensitivity and by its ability and opportunity to adapt to climate changes (Adger et al., 2003).

Uncertainty is considered a salient aspect of climate change whose quantification has been the subject of the greatest efforts among climates scientists, teasing out how much is due to our inability to model precisely the physical climate system and how much is due to our inability to forsee the evolution of the human system and its production of GHGs (Adger et al., 2003). Part of the reason why there are diverging estimates of temperature, precipitation and other variables is associated with lack of sufficient information regarding the reaction of climate system to unprecedented emissions of GHGs or information related to reactions of clouds, forest, grasslands and oceans to climate parameters. This uncertainty has an important influence on the type of adaptation actions and investment decisions and requires risk management strategies (FAO, 2015; Konrad and Thumy, 2014).

Finally, adaptive capacity is defined as the ability of a system to adjust to climate change, moderate potential damages, take advantage from opportunities and cope with possible consequences (FAO, 2015). The ability of a system to adapt to climatic stimuli greatly influences the vulnerability of communities and regions to climate change effects and hazards (AMCEN, 2011; Bohle et al., 1994; Downing et al., 1997; Kelly and Adger, 1999; Kates, 2000). In particular, the adaptive capacity depends on environmental characteristic and it is function of human development, scientific and technical knowledge, information and skills, infrastructure, institutions and equity. In this regard, countries with limited resources, low levels of technology, poor information and skills, poor infrastructures, unstable or weak institutions and inequitable empowerment and access to resources have little capacity to adapt and are highly vulnerable (IPCC, 2014). In particular, in African countries, the high levels of vulnerability and low adaptive capacity have been linked to factors including reliance on natural resources, a limited ability to adapt financially and institutionally, low per capita income and lack of safety net. As consequence, Africa in general and Sub-Saharan Africa in particular are considered one the most vulnerable region in the world in terms of climate change.

4.2. Adaptation strategies in Africa

In the African continent climate variability is a phenomenon that some societies have faced for many generations and even centuries. However, most countries remain particularly vulnerable to the on-going climate change because of limited capacity of intervention as result of widespread poverty, lack information and infrastructures, inequitable land distribution and dependence on rainfed agriculture.

In these regions, proper adaptive measures could enhance flexibility and have net benefits in water resources (irrigation and water resources, aquifer and groundwater management, desertification), agriculture (crop changes, technology, irrigation, husbandry) and forestry (regeneration of local species, energy-efficient cook stoves, sustainable community management).

Adaptation strategies change in both spatial and temporal scales with options and opportunities ranging from technological to behavioural changes. Various types of adaptation can be distinguished depending on timing, goal and motive of its implementation. These include: (i) anticipatory adaptation, which take place before impacts of climate change are observed; (ii) reactive adaptation, which take place after the initial impacts of climate change have occurred; (iii) autonomous adaptation, which does not represent a conscious response to climatic stimuli but is trigged by ecological changes in natural systems and by market or welfare changes in human systems; (iv) planned adaptation, defined as “the result of a deliberate policy decision based on awareness that conditions have changed or are about to change and that actions is required to return to, maintain, or achieve a desired state” (AMCEN, 2011).

African rural farmers have practiced a range of agricultural techniques as coping strategies and tactics to enable sustainable food production and deal with extreme events. Such strategies include (AMCEN, 2011):

- Restoring of degraded lands (in order to increase food production, cropping techniques should be improved by stabilizing the soil while enriching them with organic matter), e.g. development on stable systems based on the use of animal manure on crops in Nigeria;
- Appropriate soil tillage, which is fundamental when land become bare and subject to erosion by wind and water (one operation involves plowing the bare ground with single furrow up to 25 cm deep and 3-10m apart, depending on soil type);
- Intercropping and crop diversification, which enables better utilization of land resources and prevents the over-production of a single product;
- Use of home gardens;
- Utilization of improved crop varieties which are heat and drought tolerant, low-water-use efficient, salt tolerant for use in lands and floods tolerant for the coastal regions;
- Cropping adjustment (fallowing land for water conservation or nutrient conservation or nutrient restoration, deep seeding and wide spacing of plant, terracing to reduce run-off and conserve soil moisture in steep cultivated hillsides or areas);
- Establishment of strategic food reserves (governments and communities should establish strategic food reserves to buffer potential increases in the variations of local and national production);
- Manage crop calendar (if rains come early, long-season cultivars are planted to take advantage of their greater yield producing potential, while delays in rainy season or crop death due to prolonged droughts lead farmers to short-season cultivars of the same crops);
- Diversification of herds and incomes, such as the introduction of sheep in place of goats in the Bara province in Western Sudan;
- Pruning and fertilizing to double tree densities and prevent soil erosion in semi-arid areas, e.g. Senegal, Burkina Faso, Madagascar and Zimbabwe;

- Manipulation of land use leading to land use conservation, e.g. shift from "livestock farming" to "game farming" in Southern Africa;
- Water conservation techniques to cope with arid conditions such as the Zai technique in Burkina Faso, where farmers dig pits in the soil to collect organic material carried by the wind during the dry season while, at the start of the rainy season, they add organic material carried by wind during the dry season together with organic matter from animals. In this way, they attract termite activity resulting in termite tunnels that can collect rain deep enough that it doesn't evaporate and thus increasing soil fertility.

Although the existence of a wide range of adaptive options, existing adaptation strategies seems to be not enough to cope with future climate changes and consequently more work on adaptation policies would be required. This is the reason why, technical improvements together with local empowerment in decision making and incorporation of climate adaptation within broader sustainable development strategies could determine an enforcement of local adaptive capacity and hence a reduction of climate change vulnerability of many African countries.

4.3. Determinants of farmer's choice of adaptation strategies

Before the definition of basic elements characterizing effective adaptation strategies, it is essential to understand in depth the determinants underlying the adaptation propensity of people.

Considering social aspects, some demographic characteristics of the household head such as age, gender and education level play an important role in the adaptation choices.

The influence of age on intervention propensity has been mixed in literature. In some studies, age of household head is found not related with the farmer's adaptation propensity (Thacher et al., 1997; Anim, 1999; Zhang and Flick, 2001; Bekele and Drake, 2003; Luka et al., 2012). In contrast, other studies found that age is significantly and negatively related to farmers' decision to adapt (Gould et al., 1989; Featherstone and Goodwin, 1993; Lapar and Pandely, 1999; Burton et al., 1999; Dolisca et al., 2006; Nyangena, 2007; Anley et al., 2007; Hassan, 2008), while others assume that older farmers, having a more experience, are more reactive to climate change through adaptive actions (Diggs, 1991; Maddison, 2007; Ishaya and Abaje, 2008; Deressa et al., 2011).

Gender could be another important variable affecting adoption of adaptation practices at farm level. Gender refers to socially constructed roles, responsibilities and opportunities associated with men and women, as well as hidden power structures that govern the relationships between them (Vincent et al., 2010). In less developed countries, there are gender-specific differences in consumption patterns, lifestyles, education opportunities, access to and control of resources and power. Furthermore, in these contexts, climate change could affect men and women differently, depending on their roles and responsibilities in the household and in the community. Some studies show that climate change could have a disproportionately greater effect on women, since women are often poorer and less educated than men and often excluded from political and household decision-making process that affect their lives. Additionally, women usually have fewer assets and depend more on natural resources for their livelihoods. In the same way that gendered roles lead to differences in vulnerability between men and women, they also create opportunities for adaptation. Indeed, women are not just victims of adverse climate effects, but also potential key active agents of adaptation. In this regard, some studies show that female farmers are more likely to adapt to climate change through natural resource management and conservation practices (Newmark et al., 1993; Burton et al., 1999; Dolisca et al., 2006; Bayard et al., 2007; Hassan, 2008). This is due to their often deep understanding of their immediate environment, their experience in managing natural resources and their involvement in climate-sensitive work such as farming, forestry and fisheries (Vincent et al., 2010). However, while their lives are typically closely tied up with natural resources, women are usually excluded from decision-making processes and thus barred from contributing their unique experience and knowledge to the struggle to adapt to climate change (Vincent et al., 2010).

A further important adaptation driver is the level of education achieved by household heads. In this regard, there is emerging awareness that formal and non-formal education has an important role to play in increasing resilience and developing innovative adaptation strategies (Vincent et al., 2010). While formal education should be recognized as a basic process by which human beings and societies can reach their fullest potential, non-formal education and training should be incorporate as essential part of learning in order to improve the capacity of people to cope with climate change in practice.

Considering the economic aspect of the adaptation process, although some uncertainties around the exact estimation of adaptation costs, a recent report of UNEP (2016) estimated that the cost of adapting to climate change in developing countries could rise to $280 or $500 billion per year by 2050. The availability of high level of income at household level together with a good access to credit and financial aids could be considered essential in the immediate future in order to enhance and improve all adaptive actions.

In order to reduce climate change vulnerability, institutional arrangements are important in enhancing entitlements and access to resources adaptation. Institutions can help people to build their adaptive capacity, ensure information and provide their support to create proper conditions to reduce vulnerability to climate risks or to exploit opportunities (AMCEN, 2011). In particular, in the African context, financial requirements are key to grant mobilization of sufficient resources to invest in new adaptation technologies.

Furthermore, access to infrastructures could be considered an important factor influencing adaptation propensity. The poor state of infrastructures in most African countries is widely known as one of the major factors increasing vulnerability and lack climate change adaptation capacity. Indeed, poor infrastructure is negatively impacting basic needs for African citizen including clean water, energy, health, education, access to markets and investments (AMCEN, 2011). As result, such constraints have unavoidable consequences in terms of implementation of adaptation strategies.

Last but not the least, creation of awareness on climate change through a right perception of weather alterations is considered a prerequisite for conscious implementation of any coping strategy.

4.4. The importance of perception in the adaptation process

Literature on adaptation make it clear that, among all possible factor influencing climate change adaptation, perception is considered a fundamental prerequisite. Maddison (2007) argues that adaptation to climate change is a two-step process; the first step requires the perception of a change in climate, and the second step requires the identification of potentially useful adaptation measures and the implementation of them. This means that this element represents a basic component of any possible adaptation strategy. However, this perception of climate change could be biased due to the action of different drivers. For instance, farmers could have a tendency to overestimate the frequency of negative impacts of climate variability and underestimate benefits and positive opportunities (Cooper et al., 2008). On the other hand, poor access to right information regarding the on-going and future climate change projections can alter awareness and thus adaptation propensity. Clearly, if the decision of putting in place specific adaptation practices is based on a biased perception of climate alterations, it is likely that the strategy will be unsuccessful or even harmful to the household. This is the reason why it is crucial to understand what drivers influence a correct perception of climate change.

Some studies have identified that the availability of information regarding climate and environmental changes is crucial in enhancing awareness of climate variability. In particular, access to information on weather projections can determine a wide diffusion of climate change awareness.

Moreover, information exchange seems to be crucial in the diffusion of climate change awareness. In this regard, farmer-to-farmer extension and the number of relatives in the village represent social capital, which plays a significant role in information exchange (Isham 2002), together with extension agents, membership of environmental groups, newspaper and mass-media diffusion (Deressa et al., 2011).

Another element that can influence climate change perception is the location together with environmental characteristics of the place where household is situated. The agro-ecological setting of farmers influences the propensity to climate change adaptation. A study by Diggs (1991) revealed that farmers living in drier areas are more likely to describe the climate change to be warmer and drier than farmers living in a relatively wetter area with less frequent droughts. At the same time, it is hypothesized that farmers living in lowland areas are more likely to perceive climate change as compared to midlands and highlands (Deressa et al., 2011).

Given that perception of climate change represents an important prerequisite of proper adaptation actions, it is necessary enhance and increase the community climate change awareness.

Improvements in forecast and early warning systems are increasingly being recognized among the basic requirements for adaptation, particularly to prevent the damaging effects of floods, droughts and tropical cyclones but also to predict diseases outbreaks in epidemic prone areas (AMCEN, 2011; Tarhule and Lamb, 2003).

Also research activities play a key role in building awareness. The importance of linking research to policy-making has been emphasized along with the need to incorporate the local knowledge on coping strategies and practices (AMCEN, 2011). Furthermore, improving communication between research communities and users is a prerequisite for an aware and effective adaptation strategy. In this regard it is fundamental to identify mechanisms for ensuring the adoption and incorporation of climate information including forecasts into the livelihood strategies of different stakeholders' groups (AMCEN, 2011; Washington et al., 2004).

In conclusion, it is clear that the perception of climate changes is just one possible driver affecting the adaptation propensity. This imply that effective policy actions aimed to promote adaptive actions should be designed by taking into account different elements whose importance depends on local context considered.

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Chapter 5

Climate change and food security. A case study in Uganda[2]

5.1. Introduction

Climate change is one of the most important global environmental problems whose scientific evidences are unequivocal. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen and the concentrations of greenhouse gases have increased (IPCC, 2014b).

More than other major economic sectors, agriculture is particularly affected by these weather modifications because it is climate – sensitive and highly dependent on natural equilibriums (FAO, 2015). Increases in temperatures, rainfall variations and growing frequency of extreme weather events are adding pressure to the global agricultural systems, which are already struggling to respond to expanding global demand for food (FAO, 2015). As consequence, climate change impacts are expected to affect more severely the poorest people living in developing countries, because of their geographical and climatic conditions, their high dependence on the agricultural sector and their limited capacity to adapt to a changing climate (Dorland et al, 2003; FAO, 2015). However, these impacts are projected to be different across countries and regions (Tol et al., 2004). In this context, Sub-Saharan Africa is considered particularly vulnerable since future incidence and severity of droughts, floods, and other extreme weather events are likely to increase (Collier et al., 2008; Kotir, 2011) with expected damages on crop, livestock and fishery production (Campbell et al., 2016), increases of natural resources and water scarcity, rising health and sanitation risks and resulting exacerbation of the already precarious food security conditions (FAO, 2015). In this regard, recent evidence show that Sub-Saharan Africa remains the region with the highest prevalence of undernourishment, affecting 22.7% of the population in 2016 (FAO, IFAD, UNICEF, WFP and

[2]This chapter is partially based on my contribution to the paper: C. Perelli and G. Branca (2018), Climate change and food security. A case study in Uganda.

WHO, 2017). The situation is especially urgent in Eastern Africa, where one-third of the population is estimated to be undernourished (the sub-region prevalence of undernourishment increased from 31.1% in 2015 to 33.9 % in 2016) (FAO, IFAD, UNICEF, WFP and WHO, 2017).

Climate change will affect all four dimensions of food security, namely food availability, food access, food utilization and food stability. The importance of the various dimensions and the overall impact of climate change on food security will differ across regions and over time and, most importantly, will depend on the overall socio-economic status that a country has achieved as the effects of climate change set in (Schmidhuber and Tubiello, 2007).

Environmental and climate change can affect food availability through changes in agro-ecological conditions (Schmidhuber and Tubiello, 2007) with consequent modifications in all components of agricultural production (Iizumi and Ramankutty, 2015). In particular, climate variability may affect agriculture and food availability by altering the spatial and temporal distribution of rainfall as well as the availability of water, land, capital, biodiversity and terrestrial resources (Hanjra and Qureshi, 2010).

The effects of climate change on food access is complex and is determined by different factors such as (Burke and Lobell, 2010): (a) how much household's income depends on agriculture; (b) the nature of household's exposure to food prices; (c) the goodness of integration between local and global food markets; (d) the broader longer-run prospects for livelihood improvements.

Even if climate change has an impact on food availability and access, it can still affect food security through its effects on food utilization. This dimension could be highly influenced by climate change in three main ways (Burke and Lobell, 2010): (a) by changing the yields of important crop sources of micronutrients; (b) by influencing decisions to grow crops of different nutritional value or (c) by altering the nutritional content of a specific crop. The effect is a decrease in dietary quality as well as quantity, which is magnified by pre-existing vulnerabilities and lead to long-term losses of health, productive capacity and income (IPCC, 2014a). Climate change can also exacerbate incidence of infectious diseases (such as malaria) thereby increasing the caloric requirements of affected populations and reducing the body's absorption and utilization of essential nutrients, effectively increasing overall nutrition needs and lead to malnutrition (Huynen et al., 2013).

Finally, climate variability and higher frequency and intensity of extreme events will affect the stability of food availability, access and utilization through changes in seasonality, more pronounced fluctuation in ecosystem productivity, increased supply risks and reduced supply predictability (FAO, 2016).

In absence of well-functioning insurance markets, the greater exposure to climate risks lead to (IPCC, 2014a): (a) greater emphasis on low-return but low-risk subsistence crops, (b) a lower likelihood of applying purchased inputs such as fertilizers, (c) a lower likelihood of adopting new technologies and (d) lower investments. All of these responses, affecting both quantity and quality of food, lead to a scarce stability of all food dimensions illustrated above.

However, climate change cannot be seen as "a stand-alone risk factor", but rather as an amplifier of existing health and food security risks and an additional strain on institutional infrastructures (Huynen et al., 2013). In this regard, there is the need to explore in depth the link between climate change and food security in contexts where many other socio-economic factors can potentially influence food security conditions, under the assumption that interactions between climate and non-climate factors are vital in shaping human vulnerability to global warming (Huynen et al., 2013). In particular, the following research questions should be answered: (i) What are the main socio-economic and environmental factors affecting households' food security? (ii) To what extent climate change affect food security? (iii) What policy measures could be put in place to improve food security?

This study aims at answering these questions. It makes reference to a case study in Uganda, an African country particularly vulnerable to climate modifications.

The study is organized as follows. First, it was analysed climatic data in order to detect the on-going climate change. Second, with the purpose to estimate the prevalence of food insecurity, it was computed the Food Consumption Score

(FCS), a food security indicator designed to capture information regarding dietary diversity, food frequency and relative nutritional importance of different food groups (WFP, 2008). Third, it was used the same indicator to realize a cluster division of population in three different Food Consumption Groups (FCG's). Furthermore, considering this cluster division as a dependent variable, it was realized a regression analysis to identify food security drivers and to verify in what extent households' food security has been affected by climate change. Finally, the last part of the study discusses what issues should be taken into consideration when designing appropriate adaptation policies to enhance resilience and improve food production systems.

5.2. Materials and methods

5.2.1. Geographical context

The analysis is conducted on a case study in Uganda, a landlocked country located in the Eastern part of the African continent. It is characterized by diverse climate patterns due to the country's unique biophysical features. Rainfall varies throughout the country, with patterns ranging from "bimodal" (characterized by a first rainy season occurring from March to June and a second rainy season occurring from November to December) to "unimodal" (characterized by a unique rainy season occurring from April to September).

In Uganda, agriculture is the most important sector of the economy. It contributes to 24.8 % of the country's GDP, accounts for 52 % of the country's total exports and represents 72 % of Uganda's workforce (FAO, 2018).

Maize, beans, banana (food), cassava and sweet potatoes are the crops grown by the most of the agricultural households in the country (Uganda Bureau of Statistics, 2010). In particular, the Eastern region has the highest number of agricultural households that grew maize and cassava, the Western region leads in the number of agricultural households that grew beans and banana-food while in the Central Region most agricultural households grew banana-food followed by maize, beans, and cassava (Uganda Bureau of Statistics, 2010).

Agricultural production is mainly rain-fed and thus fluctuates significantly with the on-going climate changes that are projected to increase in frequency and intensity for the next decades. Such environmental challenges are likely to adversely affect the already precarious food security conditions of local small-scale farmers. In this regard, in Uganda the number of undernourished people rose from 6.8 to 15.2 million between 2004 - 06 and 2014 - 16, while the estimated number of children (under 5 years of age) who were wasting or stunted in 2016 was respectively equal to 0.3 and 2.3 million (FAO, IFAD, UNICEF, WFP and WHO, 2017).

5.2.2. Data

Two main data sources were used in the analysis: historical data on rainfall and temperature from Climate Change Knowledge Portal (CCKP)[3]; and socio-economic data from the Uganda National Panel Survey (UNPS), referred to the 2013/14 cropping seasons[4].

Data on rainfall and temperatures come from the monthly database CCKP. The rainfall (measured in millimetres of rain) and temperatures (measured in Celsius degrees) datasets considered in this study referred to a 50 years' period (from 1965 to 2014).

On the other hand, UNPS data were collected considering a sample of 3,123 households that were distributed over 322 enumeration areas (EAs) (Uganda Bureau of Statistics, 2014). It covered 34 EAs in Kampala district, and 72 EAs (58 rural and 14 urban) in each of (i) Central Region with the exception of Kampala District, (ii) Eastern Region, (iii) Western Region, and (iv) Northern Region (Uganda Bureau of Statistics, 2014).

The UNPS comprises a set of survey instruments, namely: (i) Household questionnaire, (ii) Agriculture Questionnaire, (iii) Woman Questionnaire and

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[3] CCKP is a central hub of information, data and reports about climate change around the world. It is the result of a close partnership between the Climate Change Policy Team of the Climate Change Group and the Information and Technology Solutions Rapid Application Development (ITSRD) of the World Bank.

[4] The UNPS data were collected in Uganda from September 2013 to August 2014, as part of a multi-topic panel household survey commenced in 2009/10 and supported financially and technically by the Government of Netherlands and the World Bank Living Standard Measurement Study – Integrated Surveys on Agriculture (LSMS – ISA) project (Uganda Bureau of Statistics, 2014).

(iv) Community Questionnaire (Uganda Bureau of Statistics, 2014). For the purpose of this study, it was considered only the information provided by the first two questionnaires. They included: demographic information of all household members (i.e. age, gender, marital status, level of education or formal schooling, health), their life conditions (i.e. labour force status, housing conditions, water and sanitation, energy use, household incomes, household expenditure, shocks and related coping strategies, welfare conditions and food security) and specific agriculture data (i.e. information on land holdings and land access rights, crop and livestock inputs and outputs, extension services, farm implements, structures and machinery).

5.2.3. Methodology

The analysis proposed here consists of three steps: (i) climate pattern analysis; (ii) assessment of food security level with the related household classification; and (iii) regression analysis.

5.2.3.1. Analysis of climate patterns

The detection, estimation, and prediction of climatic trends in the context of changing climate are vital to assess climate-induced changes and suggest feasible adaptation strategies, particularly in countries where rainfed agriculture is predominant. Time-ordered data were analysed with the aim to detect significant climatic trends in the presence of random fluctuations. To this end, temperature and precipitation were considered as climatic parameters since they represent the most important variables used to trace extent and magnitude of climate variability. A decomposition model was used because it considers important elements such as trends, seasonal factors and long-run cycles of climate time series. The basic structure of this model could be additive or multiplicative. The additive decomposition model is useful when the variation is relatively constant over time, while the multiplicative model is used when the variation increases over time. Since the present study focuses on climate change, a phenomenon characterized by increasing fluctuation in climatic patterns, the analysis was conducted assuming the following multiplicative model:

$$Y = T * S * C * E \qquad [1]$$

In equation [1] Y represents the observed data, T is the trend component, S is the seasonal component, C is the cycle component and E represent the error component (the random increase or decrease of the variable Y for a specific time period). The multiplicative model illustrated above expresses the C, S and E components as percentages above or below the underlying trend. The cyclical component C, which represents a gradual long-term irregular swing of the variable (Spiegel, 1973), can be assumed as being absent, given that no clear physical phenomenon linked to a cyclic behaviour was observed in the study area. Furthermore, the seasonal component S, which represents intra-year fluctuations that are repeated every year with respect to timing, direction, and magnitude (Spiegel, 1973), was removed from the original data utilizing a seasonal adjusted value (Yt/St). This seasonal adjustment allows to isolate and analyse the specific trend component of the time series.

The estimation of the long-term climatic change T, which is considered the most basic time series component, was obtained using the following simple regression model:

$$T = \alpha + \beta\, t \qquad [2]$$

Equation [2] represent the linear relationship existing between trend (T) and time (t).

The estimation of temperature and precipitation trends obtained following this time series analysis allowed to detect climate variations occurred in the study area during the last decades (from 1965 to 2014).

5.2.3.2. Food consumption group classification

After the detection of climate change occurred in Uganda during the last decades, the study focused on the assessment of food security level of the population living in the study area.

Food security is considered a contested, evolving, multi-dimensional construct, including both well-established dimensions such as availability, physical access, economic access (affordability), consumption and utilization (Foran et al., 2014). In face of this complexity, there is no single indicator able to capture all food security dimensions (Pérez-Escamilla et al., 2017). However, some indicators are able to capture a part of this multidimensionality. In this study, it was utilized the Food Consumption Score (FCS) with the aim to summarize as much as possible the complexity of the multidimensional food security households' status and classify our sample in homogeneous groups for further quantitative analysis.

FCS is the World Food Programme's main food security indicator which represents a proxy to assess both quantity and quality of households food consumption[5] (WFP, 2008). It is a composite indicator based on dietary diversity, food frequency and relative nutritional importance of different food groups (WFP, 2008).

By looking at quantity, value and frequency of food eaten in the past 7 days[6], out of a list of 62 items, foods were regrouped into 9 food groups and the consumption frequencies of the food items belonging to each group were then summed. Any summed food group frequency over 7 was recorded as 7. Each food group was assigned a weight reflecting its nutrient density[7] so that groups rich in proteins like meat and fish had the highest score while food groups with low energy, and micronutrients like vegetables had the lowest one (WFP, 2008). In **Table 5.1** is reported the classification of foods in 9 groups with relative weights. As illustrated, the weights are attributed with reference to the nutritional content of foods and their ability to improve the overall diet. In particular: (a) the lowest weight (equal to 0) corresponds to condiments, which have scarce impacts on the overall diet because of consumed in small quantities; (b) a weight equal to 0.5 is attributed to sugar and oil, food groups consumed in small quantities, not rich in micronutrients but energy dense; (c) vegetables and fruits

[5] The FCS was first created in Southern Africa in 1996, and has been in use there as part of the CHS (Community Household Surveillance) for 4 years and several rounds of data collection. Extensive testing and application of the FCS have validated its use in this region and context. Additionally, the FCS is now being tested and plied in other countries and regions (WFP, 2008).

[6] The dietary diversity & food frequency approach aims to estimate whether the household manages to access items from the basic food groups in their habitual diet. The number of days of consumption out the reference last 7 days (week) is intended to track potential regularities in the consumption habit (WFP, 2008).

[7] Nutrient density is a term used to subjectively describe a food's quality in terms of caloric density, macro and micro nutrient content and actual quantities typically eaten.

are characterized by a weight equal to 1 due to their poor protein, micro-nutrients and energy content; (d) a weight equal to 2 characterizes main staples, foods eaten in large quantity which are energy dense but low in terms of protein content; (e) a weight equal to 3 is attributed to pulses, a food group considered energy dense, with a high amount of protein but poor in terms of micronutrients and fat; (f) the highest weight (equal to 4) is attributed to meat, fish, and milk, which are energy dense and characterized by the highest quantity of protein, micronutrients and fat (WFP, 2008).

Table 5.1 FCS food groups and related weights

Food items	Food groups	Weight
Maize, maize porridge, rice, sorghum, millet pasta, bread and other cereals, cassava, potatoes and sweet potatoes, other tubers and plantains	Main staples	2
Beans, peas, groundnuts and cashew nuts	Pulses	3
Vegetables and leaves	Vegetables	1
Fruits	Fruit	1
Beef, goat, poultry, pork, eggs and fish	Meat and fish	4
Milk, yogurt and other dairy	Milk	4
Sugar and sugar products, honey	Sugar	0,5
Oils, fats and butter	Oil	0,5
Spices, tea, coffee, salt, fish power, small amounts of milk for tea	Condiments	0

Source: World Food Programme, 2008, p.8

With reference to the sample data considered, it was calculated the FCS multiplying each food group frequency by each food group weight, and then summing these scores into one composite score. However, such scores alone don’t show clearly the magnitude of household’s food security level. In particular, they don’t allow to classify a specific unit as food secure or food insecure. Therefore, it was necessary to identify and utilize specific thresholds to classify all households in three food consumption groups, which were identified by the World Food Programme and representing different food consumption profiles (WFP, 2008): ‘poor’, ‘borderline’ and ‘acceptable’. The thresholds adopted to classify sampled households in these food consumption clusters (Food Consumption Groups) were set according to assumptions of dietary patterns. In particular, since the households in the sample were found to be characterized by a high frequency of sugar and oil consumption (whose mean consumption was found equal to more than 7 times per week), it was necessary to use the alternative cut-offs of 28 and 42[8]. A score below 28 reflects households which is not expected to consume staples and vegetables on a daily basis and is considered to be characterized by a ‘poor’ food consumption profile. Households scoring between 28 and 42 are assessed as having a ‘borderline’ food consumption profile (score 42 reflects households with a daily consumption of staples and vegetables as well as oil and pulses). Last, households having a score higher than 42 are assessed as having an ‘acceptable’ food consumption profile (this type of diet is considered balanced and rich of basic nutrients).

5.2.3.3. The econometric model

The illustrated cluster division in three Food Consumption Groups was used to build an ordinal categorical variable which takes value ‘1’ if the household has a ‘poor’ profile, ‘2’ if the household has a ‘borderline’ profile and ‘3’ if the household is characterized by an ‘acceptable’ profile. In the proposed regression model, this variable was considered as a dependent variable whose value depends on covariates representing socio-demographic and economic characteristics of households (e.g. geographical location of the household, its extension in acres, gender, age, marital status and education level of the household head, number of household members, income, agricultural inputs used and livestock ownership) as well as climate-related events occurred during the period considered (e.g. droughts, floods and irregular rains). A multivariate ordered regression model was chosen since the dependent variable was a three-

[8]The recommended standard cut-offs to create the Food Security Consumption Groups (FCGs) “poor”, “borderline” and “acceptable” are 21 and 35. However, in populations that have high frequency of consumption of sugar and oil, the alternate cut-offs of 28 and 42 may be more appropriate (WFP, 2008).

category ordinal outcome. It is usually used to estimate relationships between an ordinal dependent variable and a set of independent variables. The ordered regression model is nonlinear and the magnitude of the change in the outcome probability for a given change in one of the independent variables depends on the levels of all independent variables (Scott Long J. and Frees J., 2014).

This model is commonly presented as a latent variable model. Variable y is defined as the observed ordinal variable and y* as a continuous unmeasured latent variable ranging from $-\infty$ to ∞ and having various thresholds points.

Considering the structural model, the continuous latent variable y* is equal to:

$$y^*_i = \sum_{k=1}^{K} \beta_k Xk_i + \varepsilon_i$$

where *i* is the observation, X are the independent variables, ε is the random error and β are the coefficients to estimate.

The measurement model is expanded to divide y* into J ordinal categories:

$$y_i = m \text{ if } \tau_{m-1} \leq y_i^* < \tau_m \qquad \text{for } j = 1 \text{ to } J$$

where the cut points (or thresholds) τ_1 and τ_{J-1} are estimated. We assume $\tau_0 = -\infty$ and $\tau_J = +\infty$. With regard to the three-category ordinal dependent variable considered in the present study, the observed response categories are tied to the latent variable by the measurement model:

$$y_i = 1 \text{ (poor)} \qquad \text{if } \tau_0 = -\infty \leq y_i^* < \tau_1$$

$$y_i = 2 \text{ (borderline)} \qquad \text{if } \tau_1 \leq y_i^* < \tau_2$$

$$y_i = 3 \text{ (acceptable)} \qquad \text{if } \tau_2 \leq y_i^* < \tau_3 = +\infty$$

Thus, when the latent variable y* crosses a cut point, the observed category changes. In the ordered regression model, both coefficients and J-1 cut points are usually estimated using maximum likelihood. After this estimation it is possible to identify the underlying probability that y will take on a particular value:

$$\Pr(y = m|x) = \Pr(\tau_{m-1} \leq y^* \leq \tau_m \mid x)$$

Substituting $x\beta + \mathcal{E}$ for y*:

$$\Pr(y = m|x) = F(\tau_m - x\beta) - F(\tau_{m-1} - x\beta)$$

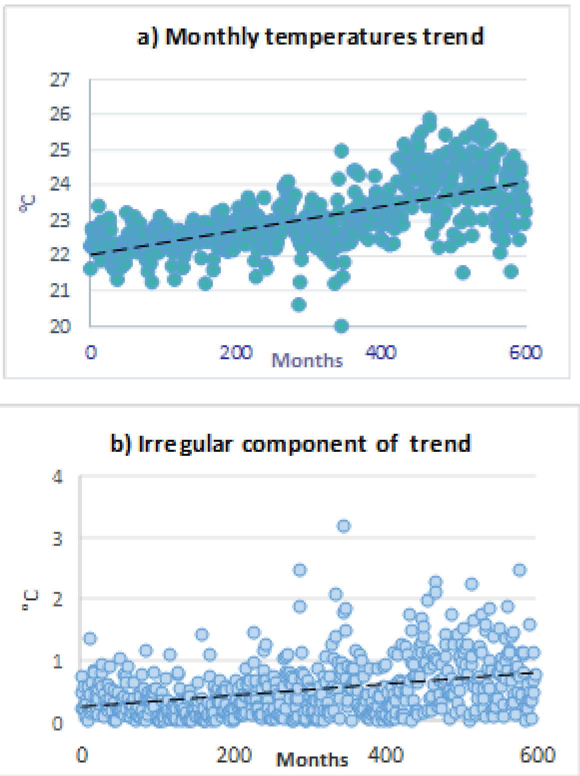
where F represents the cdf for Ɛ. In ordinal probit, F is normal with var (Ɛ) = 1 while in ordinal logit it is logistic with var (Ɛ) = $\pi^2/3$ (Scott Long J. and Frees J., 2014).

5.3. Results

5.3.1. Climate data analysis

Figure 5.1 and 5.**2** illustrate the results of climate data analysis in the period 1965-2014. They are based only on a trend component with accompanying random error. **Figure 5.1** illustrates a linearly increasing trend in temperatures. It shows that Uganda was characterized by 1.98 °C total rise in temperatures, while the irregular component, which indicates the fluctuation range of monthly temperatures expressed in absolute value, increased from 0.23 to 0.81 °C per month. These outcomes are in line with future projections of temperature in Uganda, which estimate an increase by up to 1.5 °C in the next 20 years and up to 4.3 °C by the 2080s (Hepworth and Goulden, 2008).

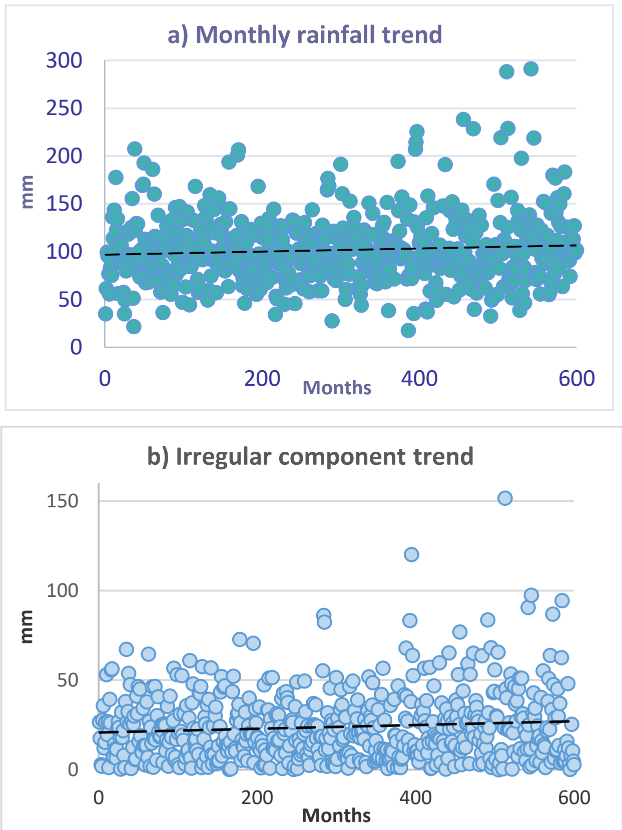
Figure 5.1 Uganda, Temperatures trend and fluctuations from 1965 to 2014



Source: Author's elaboration

Considering the regime of precipitations, Uganda climate appears naturally variable and susceptible to storms, floods, and droughts (Hepworth and Goulden, 2008). However, the past few decades have been marked by a strong climate variability, resulting in increased frequency of such extreme weather events that caused damages to natural resources and slowed social and economic development (Waithaka et al., 2013). This trend is confirmed by the results of the present analysis, which shows that irregularities in precipitations tend to increase over time. In particular, **Figure 5.2** shows that, in the 1965-2014 period, rainfall increased from 96.81 to 106.41 millimetres, with an increasing trend of the irregular component (from 20.67 to 27.27 millimetres of rain per month).

Figure 5.2 Rainfall trend and fluctuations from 1965 to 2014



Source: Author's elaboration

It is expected that future climatic trends will exacerbate these extreme events with negative implications in terms of natural resource availability, food security, human health and population livelihood (Hepworthand and Goulden 2008).

5.3.2. Food security data analysis

Table 5.2 illustrates the Food Consumption Groups (FCG) obtained by applying the thresholds illustrated in section 5.2.3.2 to the FCS scores. It shows that an important part of the households interviewed has been classified as food insecure (21.76% of them). In particular, while 16.97% of the households were characterized by a "borderline" food consumption profile with a limited variety of nutrients, 4.80% of them were classified as "poor" food consumption profile holders because of unavailability of nutritionally adequate foods.

Table 5.1 Food security status of respondent households

Food Consumption Group	Frequency	Percentage	Cumulative percentage
Poor	117	4,80	4,80
Borderline	414	16,97	21,76
Acceptable	1909	78,24	100,00

Source: Author's elaboration

Table 5.3 reports the summary statistics of the study sample. It shows that the majority of households characterized by poor and borderline food consumption profile were located mainly in the Northern region (38% and 31% respectively), while households whit an acceptable profile resulted fairly distributed in the territory. Furthermore, Table shows that the three clusters considered are mainly composed of rural households.

Considering the demographic characteristics of household heads, there were not significant differences between poor, borderline and acceptable profile holders. Indeed, in all categories, the majority of households resulted headed by middle-aged (30 – 60 years) monogamous and educated men (they attended formal school).

With regard to socio-economic factors, the majority of poor food consumption profile holders (68%) were characterized by a family with few members (less than 5). This characteristic is less persistent in borderline profile holders (54%), while the majority of acceptable ones (47%), were composed by at least 5 members (from 5 to 10 members).

Considering the household's extension (expressed in acres) the majority of poor and borderline food consumption profile holders (48% and 44% respectively) resulted owner of parcels with a moderate extension (from 0 to 1.3 acres) while the majority of acceptable ones (38%) had the availability of medium extended parcels (from 1.3 to 3 acres).

Another important difference showed in the Table concerns the use of some agricultural inputs. In particular, households with an acceptable food consumption profile were characterized by an extensive use of input (e.g. organic and chemical fertilizers, pesticides and traditional or improved seeds) compared to poor and borderline ones. On the other hand, no great differences exist between poor, borderline and acceptable profile holders in terms of income level and livestock ownership. Finally, considering climate change experiences, it seems that, during the last years, the majority of households experienced climate extreme events like drought, floods, and irregular rains, with no great differences between poor, borderline and acceptable food consumption profile holders.

Table 5.3 Sample characteristics by Food Consumption Group

Variables		*Poor*	*Borderline*	*Acceptable*
Household characteristics				
Household region	Central	14%	15%	22%
	Western	12%	28%	25%
	Eastern	37%	26%	26%
	Northern	38%	31%	27%
Household residence	Urban	13%	12%	15%
	Rural	87%	88%	85%
Household head characteristics				
HH head gender	Male	67%	65%	69%
	Female	33%	35%	30%
Age	0 – 30	22%	14%	15%
	30 – 60	56%	64%	65%
	more than 60	22%	22%	20%
Marital status	Monogamous	41%	53%	57%
	Polygamous	22%	15%	20%
	Widow/Single	37%	31%	23%
Education level	Attended formal school	67%	72%	85%
	Never attended school	33%	28%	15%
Socio-economic factors				
Number of HH members	0 – 5	68%	54%	46%
	5 – 10	27%	41%	47%
	more than 10	5%	5%	7%
HH size (acres)	0 – 1.3	48%	44%	30%
	1.3 – 3	33%	36%	38%
	more than 3	19%	20%	31%
Income[9]	Low level of income	56%	62%	59%

[9] UNPS 2013/14 collected information on various components of household income including salaries and ages, property income, investments, current transfers and other benefits, income

	High level of income	44%	38%	41%
Agriculture	Organic fertilizers	4%	5%	12%
	Chemical fertilizers	0%	2%	7%
	Pesticides	10%	8%	14%
	Traditional seeds	88%	98%	97%
	Improved seeds	10%	14%	23%
Livestock TLU	0 – 0.5	80%	76%	58%
	0.5 – 2	13%	18%	25%
	more than 2	7%	6%	18%
Climate change				
Drought, floods, irregular rains	HH affected by CC events	38%	36%	33%
	HH not affected by CC events	62%	64%	67%

Source: Author's elaboration

from enterprises and income from subsistence activities. For the purpose of the study, household income was defined as the sum of income both in cash and in-kind that came from economic activities

5.3.3. Econometric analysis

Table 5.4 illustrates the results obtained applying the multivariate ordered logistic regression model. It shows that, out of 19 variables fitted in the model, 14 appeared strongly associated with the highest level of food security (acceptable food consumption profile). These significant variables are related to (i) household regional location, (ii) gender, marital status and education level of household head, (ii) family size, (iii) parcel size, (iv) use of fertilizers, (v) use of seeds, (vi) ownership of livestock, and (vii) climate change experiences.

Considering variables related to household regional location, it is clear that the location in Central or Western areas influences positively the level of food security. In particular, for Central and Western households, the odds of acceptable food consumption profile versus the combined borderline and poor profiles are respectively 1.96 and 1.58 times greater than for the Northern ones, holding constant the other variables.

With reference to the characteristics of household heads, it was found that male headship negatively influences the household's food security level. This means that households headed by males are less likely to have an acceptable food consumption profile compared to female-headed ones (for households headed by males, the odds of an acceptable profile are 0.54 times lower than for households headed by females). At the same time, households managed by a monogamous or polygamous head are more likely to be food secure compared to those headed by a widow or single head (for households headed by a monogamous or polygamous head, the odds of acceptable profile are respectively 1.82 and 1.57 times greater than for households with a not married head). With reference to the education level, households managed by an educated head are more likely to have a high level of food security compared to those headed by uneducated farmers (for households with an educated head, the odds of an acceptable profile are 2.26 times greater than for households with an uneducated head).

With regard to socio-economic factors, our results show that the number of family members is positively associated with a high level of food security.

Indeed, for one-unit increase in the number of household members, the odds of an acceptable profile are 1.05 times greater.

Ownership of agricultural assets is strongly associated with an acceptable food consumption profile. For one-acre increase in size parcels, the odds of an acceptable profile are 1.08 times greater. Additionally, for households which use organic and chemical fertilizers, the odds of the high level of food security are respectively 1.47 and 2.78 times greater than for households which don't use such agricultural inputs. Similarly, households with access to traditional and improved seeds are more likely to be food secure than those with no access to these inputs (with odds of acceptable profile respectively 2.13 and 1.71 times greater)[10].

With reference to the livestock sector, for one-unit increase in the livestock holding, expressed in Tropical Livestock Units[11], the odds of an acceptable profile are 1.31 times greater.

Finally, with reference to climate change experiences, for households affected by drought, floods, and irregular rains, the odds of a high level of food security are 0.83 times lower than for households not affected by such extreme events. This means that farmers who experienced climate change impacts are more likely to be food insecure.

[10]The result obtained with reference to the explanatory variables "traditional seeds" and "improved seeds" could be considered apparently strange. Indeed, if we consider the use of a single crop (usually grown from seeds), the use of these two inputs should be alternative. As result, in a regression model, these two variables are correlated and could generate multicollinearity. However, the model presented in this study refers to households whose agricultural production involves different types of crops. This implies that, in the same parcel, it is possible to use: (i) traditional or improved seeds; (ii) both types of seed; (iii) neither of them. It depends on types of crops cultivated and on the process of planting utilized. As result, in the corresponding regression model, the independent variables "traditional seeds" and "improved seeds" are not redundant. This is also confirmed by the Pearson's correlation coefficient whose value is equal to – 0,0325.

[11]The number of livestock is computed using the tropical livestock unit (TLU) which is equal to 250 kg animal. The scale is: 1 bovine = 0,7, 1 pig = 0,2, 1 sheep = 0,1 and 1 chicken = 0,01 (FAO, 2009)

Table 5.2 Results of ordered regression model analysis

Food Security Level (1: Poor; 2: Borderline; 3: Acceptable) Acceptable vs. Poor - Borderline	Coefficients	Z	OR	P > | z |	
Household characteristics					
Central region (Ref. Northern)	0.672	3.92	1.958	0.000	***
Western region (Ref. Northern)	0.455	3.13	1.576	0.002	***
Eastern region (Ref. Northern)	0.021	0.15	1.021	0.877	
Urban residence (Ref. Rural residence)	0.203	1.30	1.225	0.195	
Household Head characteristics					
HH head gender (Ref. HH head Female)	- 0.624	- 4.07	0.535	0.000	***
HH head Age (Continuous)	0.004	1.24	1.004	0.214	
HH head monogamous (Ref. HH head not married)	0.597	3.57	1.817	0.000	***
HH head polygamous (Ref. HH head not married)	0.450	2.57	1.568	0.010	**
HH head education (Ref. Not educated)	0.813	5.94	2.255	0.000	***
Socio-economic factors					
Number of HH members (Continuous)	0.050	2.47	1.052	0.013	**
Income (Continuous)	- 0.071	- 0.65	0.931	0.517	
Size of parcel (Continuous)	0.076	2.94	1.079	0.003	***
Utilization of Organic fertilizers (Ref. No utilization)	0.382	1.66	1.466	0.097	*
Utilization of Chemical fertilizers (Ref. No utilization)	1.022	2.79	2.781	0.005	***
Utilization of Pesticides (Ref. No utilization)	- 0.051	- 0.28	0.949	0.781	
Utilization of Traditional seeds (Ref. No utilization)	0.755	2.74	2.129	0.006	***
Utilization of Improved seeds (Ref. No utilization)	0.539	3.56	1.714	0.000	***
Livestock TLU (Continuous)	0.266	5.17	1.305	0.000	***
Climate change					
Climate change experiences (Ref. No experiences)	- 0.186	- 1.69	0.829	0.090	*
Number of observations	322				
LR Likelihood (19)	250.57				
Prob > Chi^2	0.000				
Pseudo R^2	0.0804				

* significant at 10%, ** significant at 5%, *** significant at 1%

Source: Author’s elaboration

5.4. Discussion

The analysis' results indicate that extreme climatic events can influence household's food security status. This is in line with literature reporting that agriculture-based livelihood systems, which are already food insecure, face immediate risk of climate change-induced effects such as increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material and losses of livestock (Campbell et al., 2016). However, the experience of climate extremes is just one possible driver influencing the food security level of smallholder farmers. In this regard, the present study highlights the existence of other factors which have a more significant influence on food security[12]. These factors are related to the households' geographical location, household head characteristics, and household's socio-economic conditions. In particular, analysis' results show that geographical location in Central or Western areas has a positive effect on the probability of being food secure. This is due to differences existing among Ugandan regions. In the North part of the country, many factors underlying food security and malnutrition are most severe. Firstly, 43.5% of the population is poor, cannot have access to enough nutritious food to live a healthy and active life and are continually forced to skip meals and cut portions sizes (WFP, 2016). Secondly, a specific sub-region of Northern Uganda namely Karamoja was characterized by a peculiar climate that influences agricultural and food production. In particular, while the main part of the country is characterized by a "bimodal" climate with two different rainy seasons, the Karamoja territory has a "unimodal" climate with six rainy months followed by six dry months. This means that agricultural production in the Karamoja region relies on just one annual harvest that takes place normally in October. As result, poor harvests due to negative climatic patterns are felt more than elsewhere in the country, because resulting "food gaps" last for twice as long (WFP, 2016).

[12] In the ordered regression model, the explanatory variable related to climate change experiences is significant at 10% probability level while variables related to household characteristics (location in the central and western part of the country) household head characteristics (gender, marital status and educational level), and socio-economic factors (family members, parcel's size, organic and chemical fertilizers, traditional and improved seeds and livestock ownership) are significant at 1% or 5% probability level.

Considering household head characteristics, the results of our study highlights that male headship has a negative effect on the probability to be food secure. This result seems to be not in line with part of literature that consider female-headed households among the hardest hit by hunger (Jones et al., 2017; Kassie et al., 2014; Tibesigwa and Visser, 2016). In contrast, a growing body of evidence in international development found no significant differences in food security condition between male and female-headed households (Mallick and Rafi, 2010) or better conditions of pre-schoolers' nutritional status for female-headed households (Kennedy and Peters, 1992). In this regard, our results provide support to part of literature that considers the increasing importance of women at household and community levels a significant determinant of superior agricultural and development outcomes, including increases in farm productivity, progresses in family nutrition and improvements in the forms of both child hunger and child mortality (Farnwortha and Colversonb, 2015; Scanlan, 2004; Sraboni et al., 2014). Also, the marital status of the household head has an influence on household's food security status. In particular, households whose head is monogamous or polygamous are more likely to be food secure than households managed by a not married head. This is probably due to the socio-economic difficulties underlying this last marital status, which is more common among female-headed households[13]. Indeed, depending on her marital circumstances, a woman has different opportunities, constraints, obligations, and status within the household and the community (Verma, 2001), A female-headed household may be designed as female headed *de facto* or *de jure*. It is considered to be *de-jure* if the male member exists but stay out of the household and contributes to the economic aspect of the family. In this case, the household benefits from an external economic support and have a social recognition (the husband's presence, although "just in name", holds powerful meaning, as marriage is a norm by which all is measured) (Verma, 2001). On

[13] Considering the widowhood, in many African contexts, the number of widows is larger than the number of widowers because men can remarry without losing access to land and poverty while women cannot remarry and continue to remain on, or retain rights to their deceased husband's land (Verma, 2001).

the other hand, a female-headed household is considered to be *de-facto* if she is a widow or unmarried mother or an abandoned woman. In this case, the household head can't benefit from the husband's economic support and have limited rights because of social constraints[14] (Chant, 1997; Verma, 2001). As result, it is likely that such economic and social precarious conditions affect negatively the household livelihood and the food security condition of its members.

Furthermore, as shown by analysis' results, the educational attainment of the household head is important in explaining variations in household food security level (Smith et al., 2017). Indeed, a high education level improves the likelihood of the households being food secure, even in the context of climate change. One possible explanation is that educated farmers are expected to have more knowledge and better information to improve agricultural production, enhance its resilience to climate change and improve food systems. In this regard, this study confirms that education has potential to play an important role in ensuring food security and improving nutritional status (Keenan et al., 2001).

With reference to socio-economic factors, the number of family members influences positively the level of food security. A possible justification is linked to the greater availability of an important input like labour. Large families that employ all family members in the field could benefit from an increase in total agricultural and food production.

Size of parcels available (expressed in acres) was found to be related directly and positively to food security. One possible explanation is that the availability of large plots of land allow farmers to expand their agricultural activities and then increase total food production.

The use of some agricultural inputs such as organic and chemical fertilizers influenced positively the household's food security level. It is probably due to the effect that these inputs have in terms of yields. Fertilizers are materials of

[14] While widowhood bring some degree of personal autonomy and new measures of decision-making power for women as head of households, these gains are offset by strong social scrutiny, stigmas, and taboos (Verma, 2001).

synthetic or natural origin which contain plant nutrients (e.g. nitrogen, phosphorus, and potassium) crucial to plant growth. As result, the extensive use of these inputs could determine an important increase in the agricultural production.

Furthermore, the use of both traditional and improved seeds influenced positively the household's food security level. Probably, a household which don't use seeds in their field, based its agricultural activities on crops such as cassava, potatoes, sweet potatoes, yam and banana (crops which don't grow from seeds). Since the agricultural production of households is mainly subsistence-oriented, the exclusive production of these types of foods is not able to guarantee an equilibrate and diversified diet. In contrast, the utilization of traditional and/or improved seeds imply the possibility to produce a wide range of crops which can guarantee a diet diversified and rich in many essential nutrients.

Finally, the ownership of livestock was found directly and positively related to a high food security level. Probably, it represents a direct source of food (meat and milk) for the household members and not just an economic asset.

5.5. Conclusions

The study conducted provides interesting insights on possible drivers affecting food security in a world characterized by climate change. It proposes a rigorous method to link climate change with food and nutrition security at household level and combines the use of three different types of analysis. After a climatic patterns analysis aimed to underlying significant climatic trends in the presence of random fluctuations, a food security indicator was built to estimate the prevalence of food insecurity in rural communities and realize a classification in 3 clusters of households characterized by different food consumption profile. Finally, it was defined a regression model aimed to identify all factors affecting the level of food security and provide information about the role played by climate changes.

The first result obtained after the time series analysis confirms the existence of a real climate change in Uganda, whose magnitude increased during the last decades. These climate modifications influenced the level of food security, although the outcomes of the econometric analysis highlight the existence of other physical, cultural and socio-economic factors that have had a more significant influence on food and nutrition security. Among them emerge the geographical location of households in the study area, some demographic characteristics of household head (gender, marital status and education level), family size, economic inputs directly connected with agricultural activities (extended parcels, fertilizers and improved seeds) and livestock ownership.

Results discussed here add an important element to current literature, where the link between climate change and food security has been mostly explored in relation to impacts on crop production and food availability, with little focus on other key food security dimensions like food utilization (Esham et al., 2017). However, it is important to bear in mind the possible bias in the results of this study. Indeed, although the multidimensionality of the FCS allowed considering nutritional aspects of food security, it tends to overestimate the frequency of food secure units comparing to some other food security indicators (Lovon and Mathiassen, 2014). This implies that the results of the analysis could be affected by some inefficiencies due to possible underestimations of food insecurity incidence. In addition, since the FCS doesn’t consider all food security dimensions (e.g. food access), it doesn’t allow a comprehensive analysis. However, these inefficiencies could be ascertained by fitting the same model with other food security indicators (representing other food security dimensions) and verifying whether they are consistent with results obtained using the FCS. This further process of analysis could represent an interesting challenge for future researches.

In conclusion, all outcomes of the present study emphasize the complexity and the multidimensionality of food security under climate change and justify cross-disciplinary approaches to define and implement proper interventions.

In this regard, effective policies and actions designed to promote adaptation toward climate-smart food systems have to consider different aspects such as (a) climate change resilience and adaptation, (b) gender equalities (c) education improvements and (d) better access to agricultural inputs.

Climate change – based projects could be organized in order to obtain specific results such as enhancement of knowledge and capabilities for climate change adaptation, better access to information and improvements of agricultural systems resilience. These objectives were pursued by past projects implemented in specific regions of the country. In particular, the FAO project named “Global climate change alliance: agricultural adaptation to climate change in Uganda” (which started in 2012 and ended in 2016) followed the overall objective to contribute to the sustainable improvement of livelihood and food security of rural population in Uganda at national and decentralized level (FAO, 2017). Although some short-term results were achieved, it is important to promote this type of initiatives to address long-term impacts of climate change on food security.

Furthermore, considering the woman importance in food security and nutrition management at household and community level, the involvement of Uganda in sustainable rural livelihood programmes established in 2004, which have determined a reduction in the gender-based inequalities and an empowerment of women in terms of farm (FAO, 2010), could represents a good example of useful actions that could be implemented to improve social and food security conditions.

With regard to education, in order to create awareness among population about the importance of food security and develop skills to promote sustainable food production practices, effective policies should be realized through the organization of food and nutrition promotion activities such as demonstrations and training of climate smart agriculture practices, but also encouraging the establishment of farms or gardens demonstrations in schools and strengthening information and communication through mass media and literacy campaigns.

Finally, in order to improve access to agricultural inputs, policy actions could facilitate options which enhance access to land such as resettlement, expansion of soil and water conservation practices on farmlands (that allow a better productivity of farm units) and encourage the diffusion of effective and sustainable inputs (i.e. organic fertilizers and improved seeds) through incentives and subsidies.

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Chapter 6

Smallholder farmers' perception of climate change and drivers of adaptation in agriculture: A case study in Guinea[15]

6.1. Introduction

Sub-Saharan Africa is particularly vulnerable to climate change effects due to several ecological and environmental conditions. Such vulnerability is intensified by its dependence on agriculture, the economic sector that is most exposed to changes in climatic and environmental conditions. Moreover, this area does not benefit from a favourable enabling environment; vulnerable social and institutional networks may hinder the adaptive capacity of local communities (Thomas et al., 2007). Adaptive strategies represent a possible and viable response communities may implement to cope with adverse climate impacts, as they seek to moderate, avoid harms or exploit beneficial opportunities (IPCC, 2014).

In this frame, the work aims at studying the main factors influencing the adoption of adaptation strategies to minimize adverse climate change impacts on agriculture in vulnerable areas.

The study attempts to answer the following research questions: (i) did households perceive correctly climate change and climate variability occurred in the last decade? (ii) how did these perceptions influence households' adaptation propensity? (iii) what are the other factors that lead to the households' adaptation strategies? In the study was used data collected through a household survey carried out in 2012 in the Fouta Djallon Highlands (FDH) in Guinea[16]. The study

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[16] The data were made available through a FAO-executed project entitled "FDH Integrated Natural Resources Management Project" (EP/INT/503/GEF – 2009-2021) which was funded by the Global Environment Facility (GEF) and implemented by UNEP. The aim of this project was

is structured as follows. First it was analysed the climate data (temperatures and rainfall) recorded in two different weather stations to verify if an actual climate change can be observed during the last three decades. Second, it was assessed how the households living in the area perceived the climatic changes and to what extent they put in place adaptive strategies to cope with it. Third, it was identified possible factors influencing households' adaptation choices, by means of a logistic regression model and discuss the obtained results.

6.2. Background

Evidence of climate change has become unequivocal. Since the 1950s, many of the observed changes are unprecedented over decades to millennia. These changes have caused several irreversible impacts for biodiversity and entire ecosystems; they have hindered the development of human systems, and are expected to exacerbate current social vulnerabilities and inequalities (Otto et al., 2017).

These risks are unevenly distributed. The IPCC fifth assessment report estimates that the land temperatures over Africa will rise faster than global land average (IPCC, 2014). Sub-Saharan Africa is considered particularly vulnerable to climate change, as it is exposed to several global climatic drivers which, as a consequence of climate change, are likely to increase the incidence and severity of droughts, floods and other extreme weather events that they cause (Collier et al., 2008; Serdeczny, O. et al., 2017). Furthermore, Sub –Saharan Africa is highly reliant on the agricultural sector, which accounts for around 60 % of employment and, in some countries, more than 50 % of GDP (Collier et al., 2008). Agriculture in Sub-Saharan Africa is particularly influenced by climate fluctuations, as it is mostly rainfed and characterized by a lack use of modern cultivation techniques (Dingkuhn et al., 2006). Specifically, in West Africa most households rely on subsistence agriculture and face numerous constraints such as droughts, soil acidity, and nutrient-depleted and degraded soils (Roudier et

to mitigate the causes and negative impacts of land degradation on the structural and functional integrity of the ecosystems of the FDH and to improve rural livelihoods of the population directly or indirectly dependent on them.

al., 2011). Crop yields can be directly affected by climate variability, mostly due to the reduction of the areas suitable for agriculture, changes in the length of growing seasons, and the decrease of yields' potential (Collier et al., 2008). This is particularly true in semi-arid and arid areas, where prolonged high temperatures and droughts will become more frequent due to global warming.

Such adverse impacts of climate change could be significantly reduced through adaptation strategies (Hassan & Nhemachena, 2008).

Farm adaptation strategies can include: crop diversification (e.g. diversifying crops or changing varieties, sowing density and run-off management), variations in cropping calendars, increased use of irrigation, implementation of water and soil conservation techniques, and diversification of farming activities (e.g. keeping cereal stocks or creating off-farm employment networks). (Mation & Kristjanson, 1988). An important classification of such strategies can be found in Cooper et al. (2008): (a) ex-ante risk management options, such as the choice of risk-tolerant varieties, investments in water management, diversification of farming activities; (b) in-season adjustment of crop and resource management options in response to specific climatic shocks as they evolve; (c) ex-post risk management options that are able to minimize the impact of adverse climatic shocks on livelihoods, such as the sale of assets or the borrowing of livelihood-essential items.

The choice of the adaptation strategy to be implemented by households is influenced by many factors. Previous literature confirms that the perception of climate change can be considered as a necessary prerequisite for adaptation. Studies on the perception of climate change show that many populations have already perceived some climate alterations, both in developing and developed countries (Deressa et al., 2011). Climate change perception is influenced by different socio-economic and environmental factors (Deressa et al., 2011; Maddison, 2007). For instance, it can be biased by the subjective assessment of how "good" or "bad" a season has been: farmers show a tendency to over-estimate the frequency of negative impacts of climate change and under-estimate the positive opportunities (Cooper et al., 2008).

The way climate change is perceived is able to highly influence the choice of the adaptation strategies to be implemented, therefore positively or negatively affecting household's livelihood. With respect to the rural African context, Deressa et al. (2011) classified the factors shaping the adaptive capacity of the households in: (i) household characteristics such as education, farm and non-farm income, (ii) institutional factors such as extension services, access to information and credit, and (iii) social capital, e.g. farmer-to-farmer training and the number of relatives living in the surroundings. In other studies, the role of information about climate and production has proved to be crucial in enhancing farmers' awareness of climate change, thus driving their adaptive choices and, in general, improving their planning capacity (Hassan & Nhemachena, 2008).
The availability of physical assets such as electricity connection and ownership of machinery is also very important, as it increases the chances of farmers to take up adaptation measures (Hassan & Nhemachena, 2008).
Finally, policy strategies can be used to improve the enabling conditions for enhancing systems' adaptive capacity (Lipper et al., 2017).

6.3. Materials and methods

6.3.1. Study area

The analysis focuses on the Fouta Djallon Highlands, a series of high plateaus ranging from 900 to 1,500 metres above sea level, concentrated in the central part of Guinea and extending into Guinea-Bissau, Mali, Senegal and Sierra Leone (Ceci et al., 2014). The Fouta Djallon makes up one of the most ecologically important zones of West Africa, harbouring perhaps the highest level of biological diversity in Upper Guinea zone (Wood and Mendelsohn, 2015) and serving as the headwaters for West Africa's most economically important rivers: Gambia, Niger, Senegal and Konkouré Rivers (Ceci et al., 2014; Wood and Mendelsohn, 2015). This region is characterized by tropical climate, with a dry season in winter and a rainy season in summer, due to the south-west monsoon. The higher part of the region receives significantly higher rainfall than the lowlands, resulting from interactions among topography, oceanic proximity and prevailing warm, wet, south-westerly winds. The rainy

season lasts from May to October and annual rainfall is mostly below 2,000 mm, with lower precipitation in the northern part (Wood and Mendelsohn, 2015).
Due to their geographic and climatic diversity, the highlands and the surrounding foothills support a rich variety of ecosystems (FAO, 2008). The Fouta Djallon Highlands area is predominantly inhabited by the Fula ethnic group and extensive subsistence agriculture is still the main source of livelihood for most households. Agricultural production is mainly practiced in kitchen gardens, delimited by fenced perimeters surrounding the houses, as well as external fields in the valley bottoms, the plains and on the slopes (Ceci et al., 2014).

6.3.2. Data

For the purpose of the study, it was used two data sources: historical data on rainfall and temperature from Labè and Mamou weather stations, located near the study area; and socio-economic data collected during a household survey conducted between January and August 2012 in three specific sites inherited by the FAO project "Integrated Natural Resources Management of the Fouta Djallon Highlands" (EP/INT/503/GEF). These sites were located in the central part of Fouta Djallon Highlands: (i) the source of the Senegal River (Bafing in local language), Sub-prefecture of Tolo; (ii) the source of Guétoya, Konkouré Watershed, Sub-prefecture of Bantignel and; (iii) the source of the Gambia River (Dimma in local language), Sub-prefecture of Tountouroun. The villages where project activities were implemented have been surveyed, four in each project site for a total of twelve. The households surveyed were 296, located in the three sites as follows: 86 households in Tolo, 93 households in Bantignel and 117 households in Tountouroun. The exact number and list of families living in selected villages were not available at local administrations and traditional chiefs, so it was not possible to design a probabilistic sampling. Furthermore, households and hamlets were spread over large and impervious areas. To overcome this shortcoming, all the accessible and available households willing to be interviewed were surveyed in each village. It was estimated that 50 families at most lived in one village. The questionnaires were administered to household heads men or women, or to one of the wives of male household heads, in case they were absent for work.

The questionnaire consisted of 362 closed-ended questions and was conceptually structured upon the DfID's Sustainable Livelihoods Framework (DfID, 1999), focusing on people's perceptions and experience of resources available at the household level.

The questionnaire was divided into 9 sections, 7 out of which were taken into consideration for this study. Among the questions included in these sections, it was selected 61 variables related to the households' perception of climate change and to their socio-demographic characteristics and livelihood assets.

6.3.3. Methodology

The methodology presented in this study consists of three steps: (i) climate pattern analyses; (ii) variable selection and synthesis through Multiple Correspondence Analysis (MCA); (iii) regression analysis.

6.3.3.1. Climate patterns analysis

As in many survey questionnaires, farmers were asked about their perception of climate change in the ten years preceding the survey. It is commonly believed that farmers' memory is unlikely to reliably keep track of climatic alteration events over a longer timeframe. Additionally, many interviewed smallholder farmers might have been too young to be asked about events taking place more than ten years back. On the contrary, in order to ascertain whether actual climate change occurred in the area, climate data from meteorological stations were analysed for a period not shorter than 32 years. This allowed identifying longer term trends than mere occasional or short-term climate variability.

The analysis was conducted assuming a multiplicative relationship[17] among the time series components:

$$Y = T * S * C * E \qquad [1]$$

[17] The same formula could be re-written assuming an additive relationship exists among all elements. The choice between the two types of breaking down methods (additive or multiplicative) depends on the degree of success that it is possible to achieve applying them (Spiegel, 1973).

where Y is the observed series (temperatures or precipitations) as generated by trend (T), seasonality (S), cycle (C) and irregularity (E).

Seasonal component (S) represents monthly fluctuations that occur each year with almost same timing and intensity. These movements are due to cyclic events that take place each year (Spiegel, 1973). To measure and remove the influence of these predictable seasonal patterns, it was used an index of seasonality obtained through the method of simple averages. The seasonal adjusted values (Y') were obtained dividing the observed data by the monthly indices.

The element C is related to the long-term fluctuations, which can follow or not the same recurrent model with a constant timing. In this study, C has been assumed absent given that, during the period under analysis, no cyclic phenomenon can be observed on the data.

Thus, the time series model can be written as:

$$Y' = Y/S = T * E \qquad [2]$$

showing that the seasonal adjusted observed data is broken down into two factors; a long-time trend and a monthly irregular component. The E component is related to stochastic elements that influence the short-term variability of climatic phenomena.

Considering the aim of the study, it was assessed the long-term climatic change, i.e. the T component, through a linear regression model:

$$T = b_0 + b_{1t} \qquad [3]$$

where t stands for time (expressed in the progressive number of months starting from the beginning of available data).

6.3.3.2. Variable selection and data description

With the aim to describe the adaptation strategies implemented by households to cope with climate change, it was considered the following agricultural practices:

- Cropping calendar changes;
- Crop changes;
- Improvements in water supply;
- Utilization of native varieties;
- Utilization of short-cycle varieties;

- Long fallowing periods;
- Soil fertilization;
- Pest control;
- Weed control.

These agricultural practices can be categorized according to the classification of adaptation strategies illustrated in the introduction (ex-ante, in-season and ex-post strategies). In particular, while the first seven practices are considered “ex-ante risk management options” since they are implemented before the beginning of the season (probably as consequence of past yield losses due to climate alterations), the last two practices are classified as “in-season risk management options” since they are implemented during the season when problems occur. Among these practices, cropping calendar changes (consisting in advances or delays in planting or harvesting season) represent the risk management option most commonly used by households interviewed (it is used by 69% of the households).

Considering all these agricultural practices, a dummy variable was built to synthesize the information related to the adoption of adaptation strategies. It takes on the value “1” if the household adopted at least one of the adaptation practices considered above, or “0” if the household did not implement any of them.

Successively, the selected 61 variables were grouped in the following six categories:

- Household head characteristics;
- Natural and physical assets;
- Economic assets;
- Human and social assets;
- Food security condition;
- Perception of climate change.

Table 6.1 reports the main characteristics of the sample with respect to the groups of variables.

It shows that 69% of the households interviewed was managed by a male. As for the age, the sample was well distributed among young, middle aged and old household head (respectively, 23%, 42% and 35%). Furthermore, 69% of them declared they were educated[18].

Nearly all the households (97%) had a kitchen garden[19], and 76% had access to a traditional water well. Chemical fertilizers were only used by the 27% of the sample, while all the other households used manure to fertilize the crops. Agriculture resulted the main economic asset for 79% of the sample, but subsidies were also very common (40% of the sample). Breeding animals, especially goats (34% of the sample) were quite common among the households interviewed. Cattle was owned by 20% of the households, probably the wealthier ones (Covarrubias, Nsiima, & Zezza, 2012).

It was also evaluated the level of food security[20], which is particularly relevant in Guinea where 55% of the population live below the poverty line, around 17.5% of people are food insecure and about 100,000 children under age 5 suffer from severe malnutrition (WFP, 2014). In the sample, 69% of the household declared to be worried about access to food.

The unavailability of quantitative data on household income or investments, due to lack of record keeping by households, may represent a limitation of the analysis of the economic assets. Nevertheless, some considerations could be indirectly drawn, through the selected proxy.

[18] 69 % of household heads were alphabetized and attended at least primary school.

[19] Little home gardens used to cultivate staple crops, fruit trees and numerous useful plants.

[20] In 1996, the World Food Summit defined food security as a state in which “all people, at all times, have both physical and economic access to sufficient food to meet their dietary needs and food preferences for an active and healthy life”.

Table 6.1 - Sample description

Household characteristics		***Frequency***	***Percentage***
Household head			
Gender	Male	203	69%
	Female	93	31%
Age	Young	67	23%
	Middle aged	124	42%
	Old	105	35%
Education	Attended formal school	203	69%
	Never attended formal school	93	31%
Natural and physical assets			
Fields	Fields on the slopes	199	67%
	Fields in the valley bottoms	144	49%
	Fields in the plains	62	21%
	Kitchen gardens	287	97%
Water sources	More than 4 water sources	38	13%
	More than 4 water courses	59	20%
	Drilling	144	49%
	Boreholes	63	21%
	Water wells	226	76%
Fertilizers	Organic fertilizers	217	73%
	Chemical fertilizers	79	27%
Economic assets			
Income and subsidies	Agricultural income	235	79%
	Food aids	58	20%
	Subsidies	123	42%
	Microcredit	35	12%
Facilities	More than 4 houses	79	27%
	Toilets	229	77%
	Radio	180	61%
	Bicycle	63	21%
	Modern medicines	108	36%
Livestock	Cattle	58	20%
	Sheep	38	13%
	Goat	101	34%
Human and social assets			
Household members	More than 6 household members	143	48%
	Household members alphabetized	237	80%
	Children educated	225	76%
Labour	Provided labour to neighbours	256	86%

	Employed neighbours in the field	267	90%
Community	Participation to village administration	126	43%
	Participation to economic interest groups	163	55%
Food security			
Quality and quantity of meals	Less than 3 meals per day	104	35%
	Unable to eat the kind of food preferred	216	73%
	Limited variety of foods	218	74%
	Smaller meals	215	73%
	Fewer meals	209	71%
	No foods	131	44%
	Precarious food consumption	117	40%
	Worried about availability of food	205	69%
Climate change perception			
Temperatures	No change in temperatures	34	11%
	Increase in temperatures	186	63%
	Decrease in temperatures	75	25%
Precipitation	No change in precipitations	85	29%
	Increase in precipitations	63	21%
	Decrease in precipitations	147	50%

Source: Author’s elaboration

6.3.3.3. Econometric analysis

For the purpose of the present study, a Multiple Correspondence Analysis (MCA) was applied to the most numerous variable groups presented above (i.e. natural and physical assets, economic assets, human and social assets and food security of households interviewed) in order to synthesize the dataset with a minimum loss of information and create sets of new variables able to summarize the main environmental and socio-economic characteristics of the households.

Afterwards, it was built a logistic regression model whose main objective was to assess the adoption propensity and probability of adaptation strategies and to identify its drivers, on the basis of regressors related to the perception of climate change, natural and physical assets, economic assets, human and social assets, socio-demographic characteristics of the household head and level of food security.

As mentioned under the “Variable selection and data description” section, the dependent variable related to the implementation of adaptation strategies is dichotomous; it takes on the value “1” when the household adopted an adaptation strategy and “0” when it did not adopt sustainable agricultural practices.

As explanatory variables, it was utilized all dimensions extracted in each variable group obtained applying MCA together with a set of variables identifying some demographic characteristics of the household head and some variables describing the perception of climate change in terms of temperatures and rainfall regimes.

6.4. Results

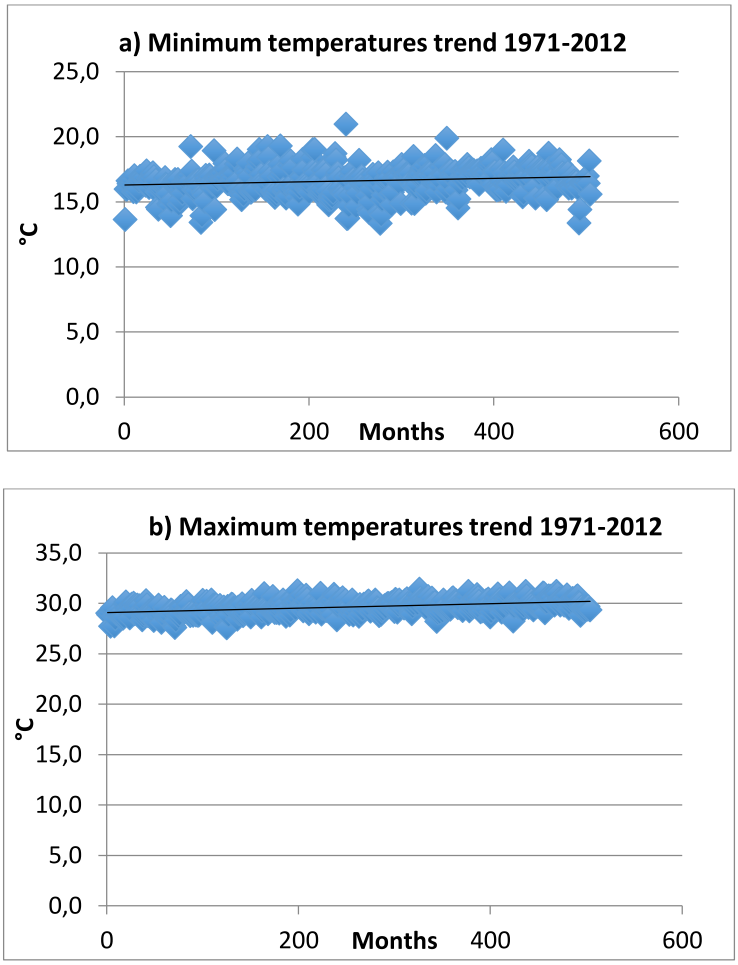
6.4.1. Climate change, actual and perceived

The results of climate trend estimations are represented in **Figures 6.1** and **6.2.** **Figure 6.1a** and **6.1b** show the trend of minimum and maximum temperatures from 1971 to 2012; minimum temperatures increased by 0.66 °C while the maximum temperatures increased by 1.11°C.

With respect to the coefficient of determination[21], in the first model (minimum temperatures) r-square is close to zero (0.036) while in the second model (maximum temperatures) it is 0.254. This means that the model related to maximum temperatures fits better climatic data than the model related to minimum temperatures.
Considering the changes in rainfall regimes occurred from 1981 to 2012 (**Figure 6.2a, 6.2b** and 6.**2c**), the annual average of millimetres of rains increased by 19 millimetres, the average number of precipitations decreased by 4.7, while their intensity (which was obtained dividing millimetres of rain by number of precipitations) was characterized by an increase of 8.1 millimetres. While the r-squared of the first model (amount of rain in millimetres) is not very high (0.270), models related to the number and the intensity of precipitations have a high goodness of fit (represented by an r-squared equal to 0.797 and 0.740 respectively).
The results show that, in the last decades, the study area has been affected by changes in climate, namely an increase in temperatures (in particular the maximum ones) and an alteration in the regime of precipitations. Evidences appear consistent with the climate change perception of households interviewed in Tolo, Bantignel and Tountouroun. Indeed, as showed in **Table 6.1**, only 11% of households interviewed did not perceive any change in temperature, while 29% of them reported no changes in the rainfall patterns. On the other hand, most of the households reported an increase in temperatures (63%) and a decrease in precipitations[22] (50%) occurred in the ten years before the survey.
It was expected that farmers who accurately perceived changes in climate may have implemented adaptation strategies able to reduce losses or capitalize on the opportunities associated with the climate changes.

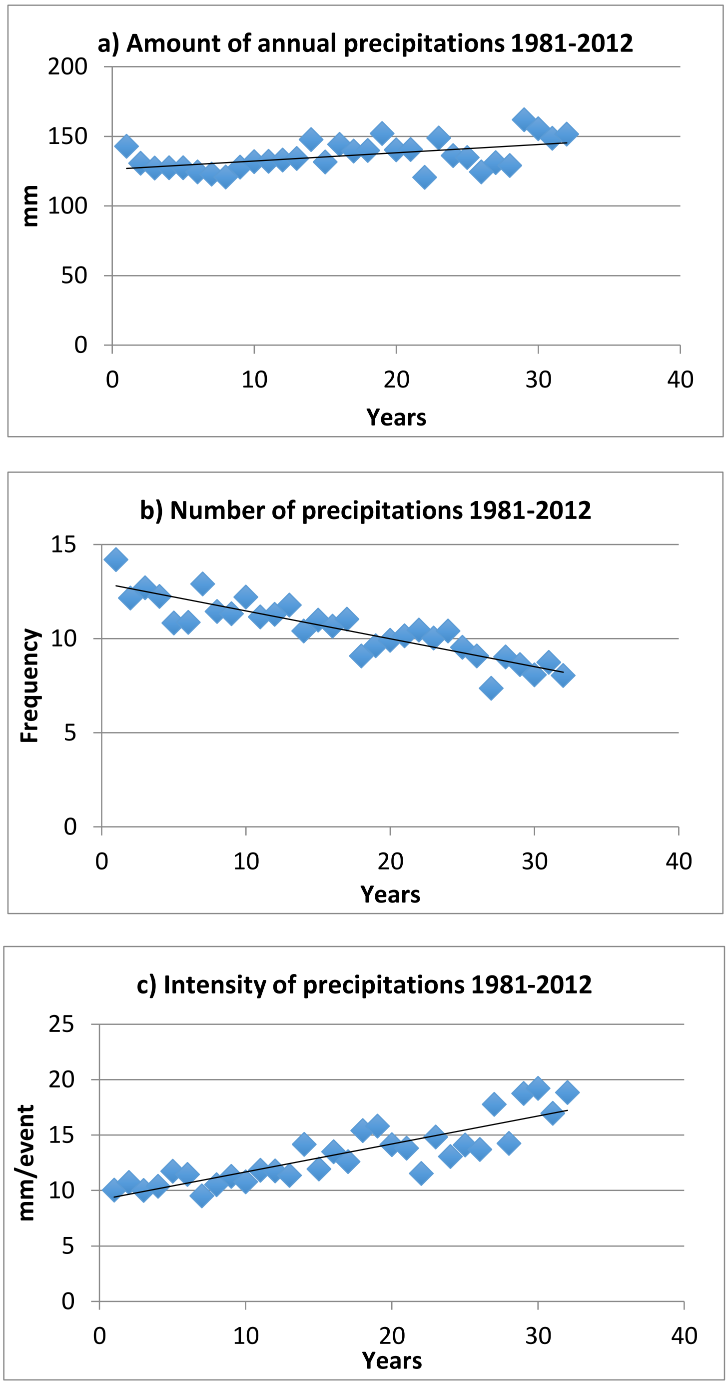
[21] In statistics, the coefficient of determination represents the proportion of the variance in the dependent variable that is predictable from the independent variables. In particular, it is a statistical measure of how close the data are to the fitted regression line.
[22] The hypothesis underlying the study was that people considers the number of storms occurred each year as an element to evaluate changes in precipitations. The amount of rain fallen and the intensity of storms (both expressed in millimetres) were considered a too specific information to be grasp by local community.

Figure 6.1 Temperature trends from 1972 to 2012



Source: Author's elaboration

Figure 6.2 Precipitation trends from 1981 to 2012



Source: Author’s elaboration

6.4.2. Multiple Correspondence Analysis (MCA)

The implementation of the MCA analysis on the four most numerous groups of variables (natural and physical assets, economic assets, human and social assets and food security condition), allowed to define a series of new variables representing the main socio-economic characteristics of the sample. The results of this analysis are presented in **Table 6.2**.

As shown in the Table, in the first group of variables (natural and physical assets), the maximum number of dimensions that could be extracted from the model was four. However, the first dimension alone was able to explain about 72% of the inertia[23]. This means that the relative frequency reconstructed from one dimension could reproduce 72% of the total chi square value. As result, it was extracted only this first dimension and it was interpreted through the analysis of MCA plot[24] (**Appendix**) and indicators such as mass, quality of representation and contribution of each variable. The analysis results showed that the dimension extracted was related to the access to water sources. Indeed, it compares households that had a good water access (water sources and courses, drilling boreholes and water wells) with households characterized by a poor access.

With respect to the "economic assets" variables group, it was extracted the first two dimensions because they explained about 57% of total inertia. Analysing the MCA plot and interpreting the corresponding parameters, it was possible to observe that the first dimension was related to the household's wealth. Indeed, it compares the households whose main source of income was the primary sector, had access to basic services (i.e. toilette) and used modern medicines, with households whose source of income was diversified, did not have access to basic services and did not use modern medicines. The second dimension was related

[23] As general rule, for each group of variables it was extracted a number of dimensions that explain at least 50% of total inertia.

[24] It is possible to represent graphically the relationships among variables using the MCA plot. This graph shows a global pattern within the data. The variable categories are represented by points whose colour is different from one variable to the another. The distance between any points gives a measure of their similarity (or dissimilarity).

to the extent of investments in livestock. It was found here the households which owned many bovines, goats and sheep.

The results of the MCA analysis on the “human and social assets” variables group showed that the first dimension explained about 71% of the inertia. It was extracted only this first dimension which appeared related to social relationships of household members. Indeed, in the corresponding axis, it was found the households which did not provide labour to neighbours, did not employ neighbours in agricultural activities and did not participate in the village administration and economic interest groups.

Finally, analysing the results of the MCA analysis on the group of variables representing the level of food insecurity, it was possible to observe that the first dimension explained almost the total inertia. In the corresponding axis, it was found households which were characterized by a limited access to a proper food variety, poor portions of foods, few meals per day, few resources to buy foods, and households which perceived an instability of their food consumption.

Table 6.2 MCA output by categories of variables

Variabiles Group	*Total Dimensions*	*Dimensions Extracted*	*Inertia explained (%)*
Natural and physical assets	4	Dimension 1	71.83%
Economic assets	6	Dimension 1	35.64%
		Dimension 2	21.08%
Human and social assets	4	Dimension 1	71.12%
Food insecurity	2	Dimension 1	95.95%

Source: Author’s elaboration

All dimensions extracted in each group of variables are summarized in **Table 6.3**.

These 5 dimensions were considered as consolidated explanatory variables of a regression model whose outcome was the adaptation to climate change and whose regressors, illustrated in **Table 6.4**, represent the main socio-economic and environmental characteristics of households considered.

Table 6.3 MCA dimensions

Variable Groups	*Dimension extracted*	*Dimension Name*
Natural and physical assets	Dimension 1	Poor access to water sources
Economic assets	Dimension 2	Good level of wealth
	Dimension 3	Good level of investments
Human and social assets	Dimension 4	Limited social life
Food insecurity	Dimension 5	Food insecurity

Source: Author’s elaboration

Table 6.4 Description of the independent variables

Explanatory Variables	*Description*
Perception of no changes in temperatures	Dummy, takes the value of 1 if HH didn’t perceived changes and 0 otherwise
Perception of increases in temperatures	Dummy, takes the value of 1 if HH perceived changes and 0 otherwise
Perception of decreases in temperatures	Dummy, take the value of 1 if HH perceived changes and 0 otherwise
Perception of no changes in precipitations	Dummy, takes the value of 1 if HH didn’t perceived changes and 0 otherwise
Perception of increases in precipitations	Dummy, takes the value of 1 if HH perceived and 0 otherwise
Perception of decreases in precipitations	Dummy, takes the value of 1 if HH perceived changes and 0 otherwise
HH head male	Dummy, takes the value of 1 if male and 0 if female
Age of HH head	Continuous
HH head educated	Dummy, takes the value 1 if educated and 0 otherwise
Poor access to water sources	Continuous (dimension extracted by MCA)
Good level of wealth	Continuous (dimension extracted by MCA)
Good level of investments	Continuous (dimension extracted by MCA)
Limited social life	Continuous (dimension extracted by MCA)
Food insecurity	Continuous (dimension extracted by MCA)

Source: Author’s elaboration

6.4.3. Regression model

The results of the logistic regression model are shown in **Table 6.5**. Out of the 14 variables fitted in the binary logistic regression model, 6 variables influenced the choice of adaptation strategies of the households interviewed, namely: perception of increases in temperatures, perception of both increases and decreases in precipitations, education level of household head, access to water sources and level of wealth.

As shown in **Table 6.5**, the variable representing the perception of an increase in temperatures was significant at 10% probability level and was positively related to the adaptation propensity. In particular, the odds of adapting (versus not adapting) for households which perceived rises in temperatures were 2.63 times greater than for households which did not perceive these changes (holding constant the other variables). At the same time, the perception of changes in precipitations were found to positively and significantly influence households' adaptation propensity (at 1% probability level). As result, the perception of changes in temperatures and precipitations could be considered an incentive to adopt relevant coping strategies.

The household head's educational level was important in explaining farmers' attitude towards adaptation to climate change and variability. The odds of adapting for households managed by an educated head were 3.15 times greater than for households managed by an uneducated head.

With regard to the availability of agricultural assets and natural resources, the variable representing a poor access to water sources was found significant at 5% probability level, with a positive influence in the household adaptation propensity.

Last, considering the economic condition of households, a good level of wealth (which is connected to a low reliance of household's income on agricultural sector and to the availability of basic and modern services) was found to negatively and significantly influence household predisposition to adopt adaptation strategies at 10% probability level.

Table 6.5 Results of the logistic regression model analysis

Explanatory variables	Coefficient	Wald	OR	P > | z |	
Climate change perception					
Perception of increases in temperatures	0.9683	1.85	2.6335	0.064	*
Perception of decreases in temperatures	0.6687	1.18	1.9518	0.237	
Perception of increases in precipitations	3.7217	560	41.3382	0.000	***
Perception of decreases in precipitations	3.7448	5.96	42.3016	0.000	***
Household head					
HH head male	0.5524	1.56	1.7374	0.120	
Age of HH head	- 0.0012	-0.12	0.9987	0.903	
HH head educated	1.1483	3.38	3.1530	0.001	***
Natural and physical assets					
Poor access to water source	0.3806	1.96	1.4632	0.050	**
Economic assets					
Good level of wealth	-0.3236	-1.72	0.7235	0.086	*
Good level of investments	-0.2276	-1.45	0.7964	0.147	
Human and social assets					
Limited social life	-0.0631	-0.37	0.9388	0.712	
Food insecurity	0.0691	0.42	1.0716	0.672	
Constant	-4.8075	-5.13	0.0081	0.000	
Number of observations	296				
LR $Chi^2(12)$	119.62				
Prob>Chi^2	0.0000				
Pseudo R^2	0.2950				

*significant at 10%, ** significant at 5%, *** significant at 1%

Source: Author's elaboration

6.5. Discussion

Despite previous literature argues how perceived changes may not always reflect the actual context (Cooper et al., 2008; Niles and Mueller, 2016), results obtained in the present study demonstrate that, in the presence of significant increases in temperatures and important alterations in the regime of precipitations, most households properly perceived the on-going climate change. Such climate change awareness implies that adaptation choices are not biased by a subjective assessment of seasonality in productivity rates. Proper perception of actual changes in climate plays an important role in determining the adaptation strategies and the positive impact they can generate on the households' livelihoods. This finding appears in line with part of previous literature which highlights how climate change awareness is an important element in the adaptation decision making (Maddison, 2007; Hassan & Nhemachena, 2008; Deressa et al., 2011). Maddison (2007) considers the adaptation to climate change as a two-step process: perception of a change in climate is followed by the identification and the implementation of potentially useful adaptation measures. This means that climate change awareness represents a basic component of climate change adaptation and requires an understanding of climate change causes and impacts (Niles and Mueller, 2016). Interestingly, it was found that no over-estimation of negative impacts of climate change, nor under-estimation of positive effects of weather modifications, altered the households' decision-making process in the selection and implementation of adaptive strategies.

Looking at the variables affecting the adaptation propensity, study' results shows that HHs' education level has a positive effect on the probability to adapt to climate change. Farmers who have followed at least primary school appear more incline to implement adaptation strategies. This is consistent with the studies showing that a high level of education can stimulate household's awareness on climate change, their propensity to implement adaptation strategies and their participation to different development and natural resource management initiatives (Anley et al., 2007; Dolisca et al., 2006; Deressa et al., 2011; Kibue et al., 2015). Furthermore, it is proven that a higher level of education determines an improvement in the farmer's ability to receive, decode and understand information on climate change (Maddison, 2007).

Among all socio-demographic drivers of climate change adaptation, various studies have shown that gender is an important variable affecting the predisposition to adaptation at farm level. In some cases, female farmers have been found to be more likely to adopt natural resource management and conservation practices (Bayard et al, 2007; Dolisca et al, 2006; Kibue et al., 2015), while in other cases it seems that male-headed households tend to adapt more readily to climate change (Deressa et al, 2011, Zamasiya et al., 2017). However, in this study it was demonstrated that the household head gender is not a significant factor influencing farmers' strategies. This result is surprising in a context like FDH where most rural women suffer from marginalization, social and cultural discrimination and have a low level of education. This status affects their ability to access information, agricultural extension services, inputs and improved technologies (Ceci et al., 2014). However, a possible explanation of such a scarce gender influence on the adoption of adaptation practices could be linked to the crucial role that women have in the household economy. Indeed, they usually take on various responsibilities in agricultural production, processing and small-scale commerce, as men and young people leave the household searching for job opportunities elsewhere (Ceci et al., 2014). Being directly involved in agricultural activities, they have a good knowledge of weather patterns which determine the same possibility of rural men to detect climate changes and adopt effective adaptation practices.

Previous literature has expressed mixed standpoints on the influence of age on climate change adaptation. Indeed, while some studies found that age is significantly and negatively related to the adaptation attitude (Anley et al, 2007; Baylard et al, 2007, Deressa et al. 2011; Zamasiya et al, 2017), some other studies highlight the inexistence of a real influence of age on farmer's decisions to adapt (Anim, 1999; Bekele & Drake, 2003; Thacher et al., 1997; Hassan and Nhemachena, 2008; Zhang & Flick, 2001). The findings of this study are in line with the latter studies and confirm a scarce influence of age on adaptation policies.

Considering household's access to natural resources, study's results highlight that limited access to water sources encourages the adoption of adaptation strategies. Scarce access to water sources make farmers mostly dependent from rainfall regimes and may have forced the majority of households (69%) to modify their cropping calendar in consideration of precipitation changes occurred during the last decades. This ex-ante risk management option could represent the only solution in a context characterized by poor economic conditions which make difficult the adoption of other more expensive adaptation strategies (e.g. improvements in water supply, use of drought tolerant or short-cycle varieties).

With respect to the household's economic condition, study's results show that households whose main source of income are off-farm activities bear a lower climate risk and have less need to adapt their agricultural practices to climate change (their livelihood is not dependent by agricultural sector).

6.6. Conclusions

A proper perception of climate change had a significant influence on the propensity to adapt. However, household head's education level, access to water resources and households' overall economic conditions showed a substantial impact on farmer's decision-making process to adapt. In this regard, effective policy actions should embrace different areas of interest: (i) climate change awareness; (ii) education; (iii) resource's access; and (iv) wealth of local communities.

Farmers' perceptions, when consistent with actual changes in climate patterns, may guarantee the effectiveness of specific adaptation strategies such as cropping calendar changes, crop's variety changes, improvements in water supply and so forth. Enhancing climate change awareness can be achieved through policies aimed at strengthening weather and climate information systems as well as knowledge dissemination.

Mainstreaming climate change issues and adaptive strategies in the education programs can contribute to improve knowledge and skills of local communities but also to increase their awareness regarding the impact of climate change in terms of agricultural productivity.

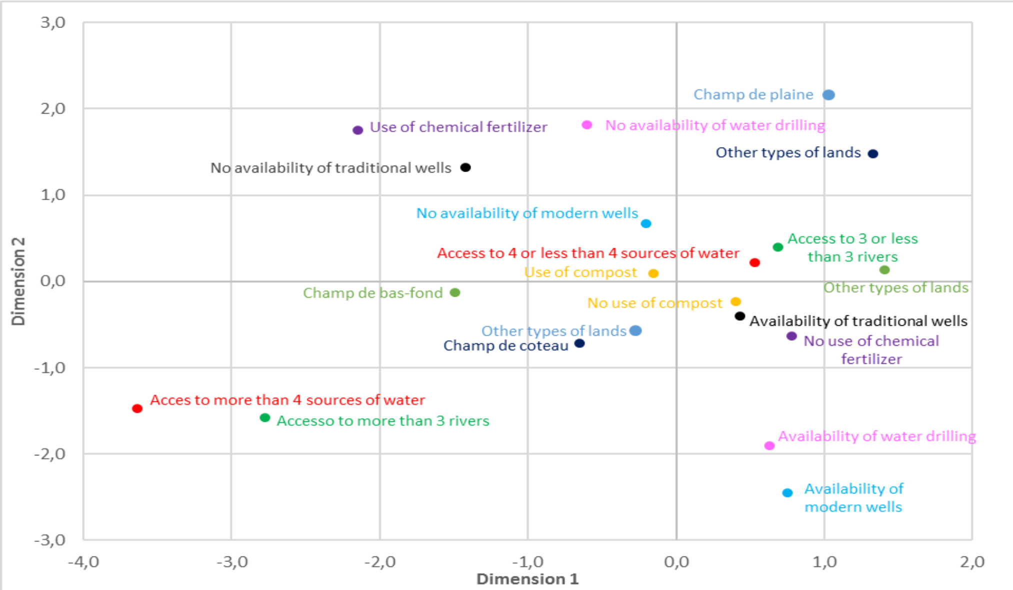
Policies focused on an improvement of infrastructure and irrigation systems could determine a reduction of climate change risk and an increased reliance of agricultural activities of local communities.

Last, innovative aspects of the study are highlighted here. In the literature, a large number of quantitative studies linking the adoption of adaptation strategies with the historical climate change data can be found. Nevertheless, very few examine the influence of climate change perception on the adaptation propensity of people affected by it. Possible future studies could examine more in depth this relationship focusing on the influence that climate change perception has in terms of adoption of adaptation approaches and practices.

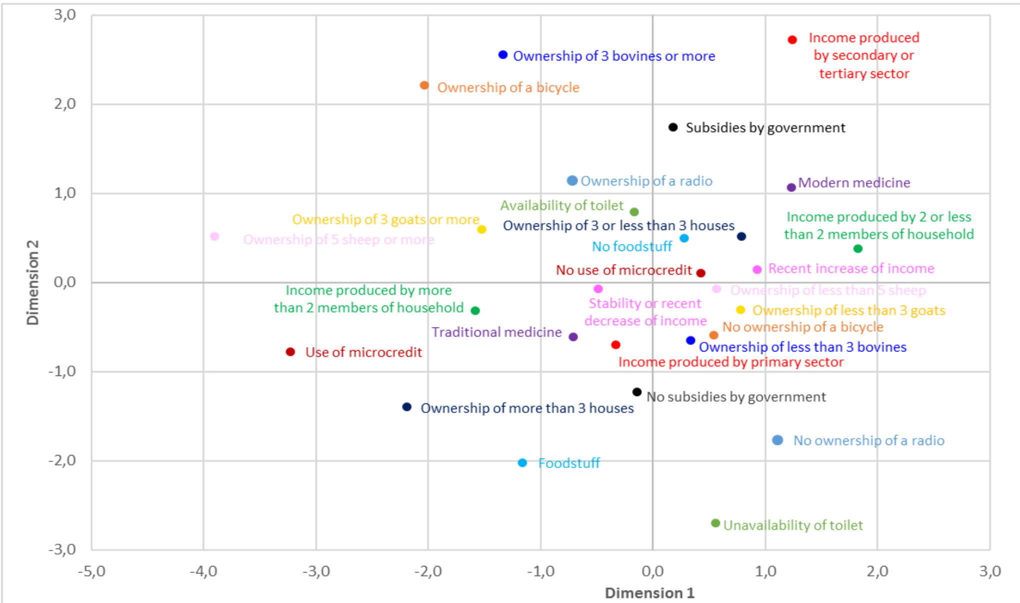
Appendix

MCA plots by category of variables

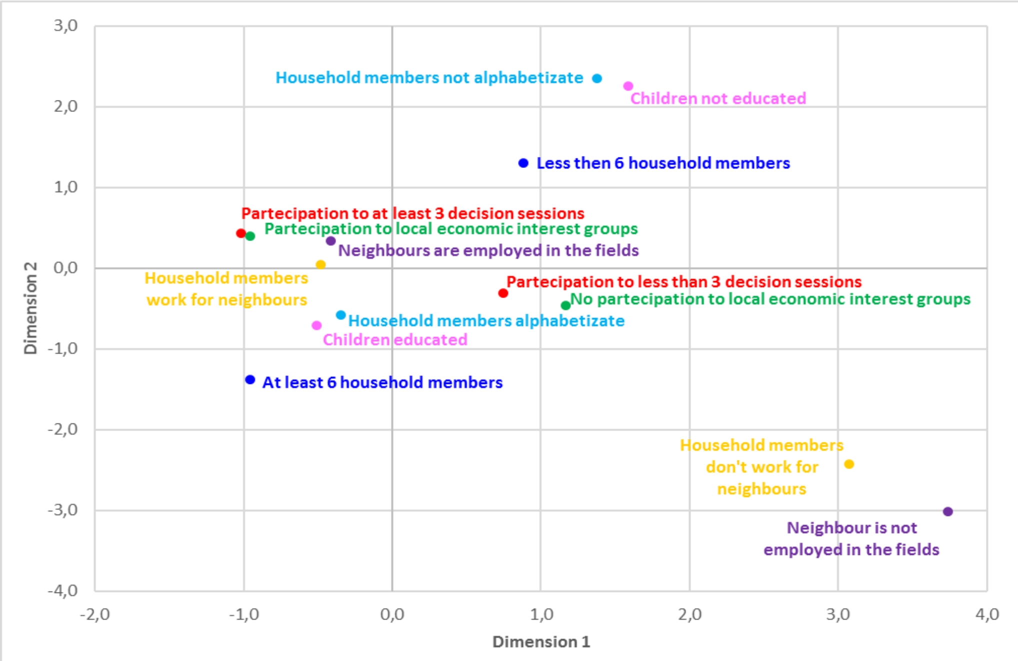
a) Natural and physical assets



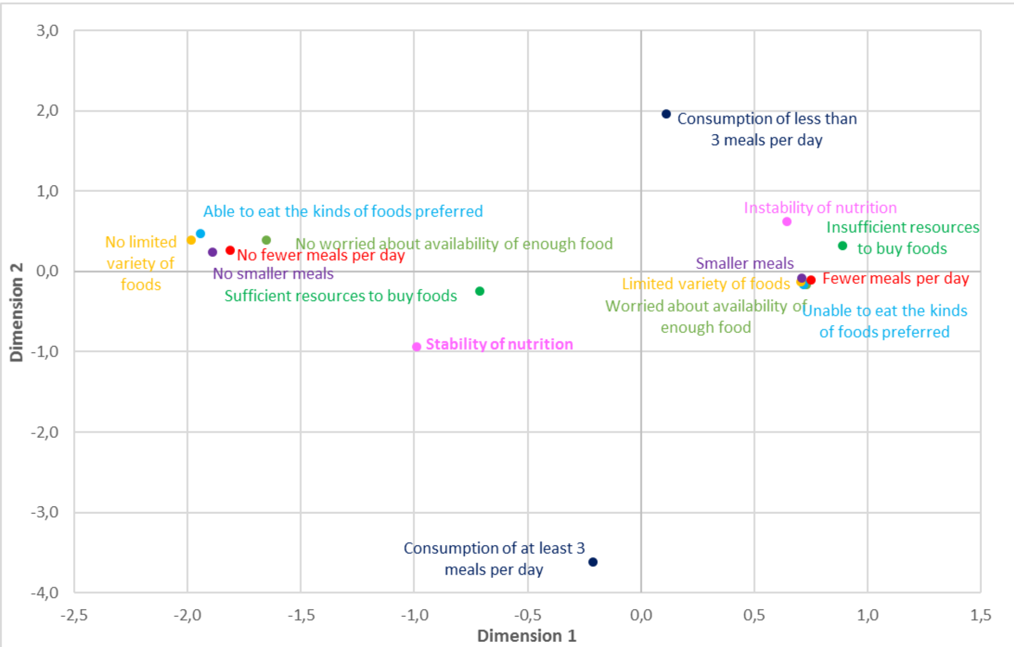
b) Economic assets



c) Human and social assets



d) Food security



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Chapter 7

Conclusions

7.1. Summary of the findings and answer to the research questions

Smallholder farmers living in developing countries face big challenges to achieve food security, particularly in a world characterized by a progressive climate change, whose impacts are sometimes difficult to identify and assess. In this context an immediate intervention is needed to preserve livelihood of rural communities. Firstly, it is necessary to understand clearly the link between climate change and food security dimensions. Once identified the magnitude of this connection, there is the need to anticipate adverse climate change impacts through proper adaptation strategies aimed to prevent or minimize damages and take advantages from opportunities. However, these adaptive actions have to be designed taking into account all possible drivers that address farmers' decision making. In this regard, a proper analysis of possible elements that could have an influence on households' propensity to adapt is also required.

The thesis implements each step of this analysis' process by investigating firstly the existence of a connection between climate change and food security, and then examining some possible drivers influencing the adoption of proper adaptation strategies. Two different case studies in Sub-Saharan Africa are used as empirical examples.

Study's results provide answers to research questions addressed in Chapter 1.

1. *a) To what extent climatic changes affect food security? What are the other socio-economic factors affecting household's food security? c) What policy measures could be put in place to improve food security under the on-going climate change?*

Chapter 5 provided insights on the connections existing between climate change and food security. Findings show that climate change (increases in temperatures and rainfall irregularities) occurred in Uganda during the last decades (from 1965 to 2014) has influenced significantly the level of food and nutrition security, together with other physical, cultural and socio-economic factors such as geographical location of households, demographic characteristics of household head (gender and education level), family size and some agricultural inputs (parcel size, fertilizers and improved seeds).

These results emphasize the complexity and the multidimensionality of food security under climate change and justifies cross-disciplinary approaches to define and implement proper interventions. In this regard, policy actions should embrace aspects related to climate change adaptation, gender equalities, education and access to agricultural inputs.

2. *a) Do households perceive properly the on-going climate change? b) How does this perception influence their adaptation propensity? c) What are the other factors that lead to the adoption of adaptation strategies?*

The analysis presented in Chapter 6 showed that, in face of climate changes (increases in temperatures, increases in millimetres of rains fallen, decreases in the number of rainfall and increases in precipitation intensity) occurred during the last decades (from 1981 to 2012), most households have had a correct perception. In particular, 63% of them have perceived increases in temperature while 50% have perceived an overall decrease of rainfall. The results highlight also the key role played by this awareness in determining the adaptation strategies and emphasize also the existence of other socio-economic factors influencing adaptation choices, namely the educational level of the household head, access to water sources and overall economic conditions of farmers. Policy actions aimed to foster the adoption of adaptation strategies may involve: enhancement of climate change awareness and access to education; knowledge and information diffusion; strengthening of resource’s access; and improvements of the economic conditions of rural communities.

7.2. General conclusions and policy implications

At the base of a general conclusion there is the evidence that food security and its nutritional aspects are significantly affected by climate change, a phenomenon whose perception is able to influence the choice of adaptation strategies. Furthermore, through the thesis emerge the importance of human capitals (e.g. education level), which can simultaneously affect the level of food security and the adaptation propensity. In this regard, composite and proper policy actions aimed to improve food security under climate change and, at the same time, promote the diffusion of effective adaptation strategies should be promoted. In particular, they should strengthen school programs, enhanced and integrated with activities or training courses aimed to develop skills, promote proper food and nutrition practices and encourage the diffusion of climate-smart agriculture technologies.

The thesis contributes to fill some research gaps. Although many studies have analysed the existence of a link between food security dimensions and global warming, only the connection between food availability and climate change was studied in depth, with little emphasis on other components that guarantee food security (Esham et al., 2017). The thesis fills this research gap, by utilizing a food security indicator (FCS) to build a regression model aimed to verify the influence of climate change on food and nutrition security. Such indicator, designed to capture information regarding dietary diversity, food frequency and nutritional content of food (WFP, 2008), allowed us to introduce nutritional aspects into a quantitative analysis.

A second novelty of this work is related to the provision of some interesting insights into the motivations underlying the choice of adaptation strategies of smallholders. It demonstrates that farmers are significantly influenced by the perception of modifications in temperatures and precipitations, which can correspond or not to real climate changes. Such results contribute significantly to the current literature, which is characterized by a large number of quantitative studies linking the adoption of adaptation strategies to real climate change data, but lack of studies analysing the influence of climate change perception on adaptation decision making.

The validity of the results presented here are limited by the unavailability of quantitative data (due to lack of record keeping by households) which could make possible the assessment of some additional factors. For example, in the

Uganda case study, the unavailability of information such as height and weight of adults and children didn’t allow an evaluation of aspects such as undernutrition, underweight and wasting. This impeded a depth understanding and an accurate description of real food insecurity conditions of local population. Furthermore, in the Guinea case study, the unavailability of data related to household income and investments have determined the impossibility to make an in-depth assessment of the impact of household economic conditions on the adaptation strategies.

References

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